Sewage Research

Effect of Certain Acids on Sludge Digestion[1]

By H. W. Clark[2] and George O. Adams[3]

Probably more research work is being carried on at the present time in regard to the digestion of sludge than on any one phase of sewage treatment. Certain principles of digestion have been fairly well established while others require further study. There seems to be a tendency to draw definite conclusions from a more or less limited amount of experimental work and to a lesser extent to attempt to apply data from one sludge digestion plant or experiment to another without taking into consideration the fact that the digestion of each sludge is a separate problem. Speaking generally, the presence or production of organic acids retards digestion. The actual amount of free acid present is very important. Certain amounts can be destroyed readily by fermentation while slightly larger quantities will permanently stop fermentation. Results of experiments outlined later in this paper have shown that a sludge which is in active fermentation will tolerate larger amounts of acid than a sludge which is just beginning to ferment.

The present study is concerned with the effect of different acids on digestion of sludge from Lawrence sewage. Investigations of this sort can be carried on more satisfactorily on a laboratory than on a plant scale, as a greater number of tests can be made at the same time and under better control than is possible with investigations on a larger scale.

The sewage used at the Lawrence Experiment Station is pumped through about 1500 feet of pipe. Over the entrance of this pipe is a strainer which excludes the coarser suspended solids. On account of this the sludge settling in tanks at the Experiment Station is of such a nature that only rarely is its pH below 6.0; this indicates that the strainer removes certain materials rich in carbon. Hence, the pronounced carbon dioxide and methane stages of fermentation reported at many places are less marked with Experiment Station sludge. To show this to be true, two bottles of sludge to which small amounts of vegetable matter were added to increase the carbonaceous matters of the sludge quickly became more acid than our normal sludge and the carbon dioxide and methane stages of fermentation were noticeable.

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Over one hundred sludge digestion experiments in gallon bottles have been carried on at the Experiment Station during the last three years, together with studies of digestion in Imhoff tanks of capacities varying from 300 to 1250 gallons. (Reports of the Lawrence Experiment Station and an article entitled "Sludge Digestion and pH Control" in the *Journal of Industrial and Engineering Chemistry*, March, 1929, describe a portion of these investigations.) Some irregular results have been obtained, such as a sudden cessation of fermentation or sudden activity after a long dormant period, which were out of line with similar digestion experiments in bottles in this laboratory. To avoid drawing possible erroneous conclusions from one series of digestions it was decided in this study upon different acids to run five separate series several weeks apart. So many variables enter into sludge digestion, however, that it is not at all certain that results similar to those obtained in the series of experiments outlined here would be obtained with sludge from another source.

The digestions were carried on in gallon bottles fitted with rubber stoppers through which passed three glass tubes. One tube reached to just above the surface of the sludge, which was about three inches in depth; the second reached about half-way down the bottle and was bent at its upper end in order to deliver liquid to a beaker placed beside the bottle. As gas was evolved and collected in the upper part of the bottle, an equivalent volume of liquid was forced through this tube. This liquid, after being measured, was returned to the bottle through the first tube, displacing gas through the third tube reaching just through the stopper and provided with rubber tubing and a pinch-cock. Except while delivering gas, this tube was kept closed. This method of measuring the volume of gas proved more satisfactory than collecting it over water and although there is some loss of dissolved carbon dioxide through exposure of the liquid to the air there is also a loss through solubility in water by the other method.

Known amounts of Lawrence sludge were added to a series of bottles which were then filled with sewage and kept at an average temperature of 70° F. One bottle was operated as a control. The pH of six others was gradually reduced to around 5.2 with normal solutions of the following acids: acetic, butyric, formic, lactic, oxalic and sulphuric. These represent four types of acids—the lower fatty, an hydroxy, a dibasic and a mineral acid. Lactic acid is the one most likely to be formed in acid sludge with possibly small amounts of other organic acids. A number of digestions were made in parallel in which the organic acid was added as the sodium salt of each acid. Contradictory results were obtained, so it is not certain whether the free acid or the salt is the more readily destroyed. This point is of interest in connection with the neutralizing of acid sludge with lime.

The condensed results of the five series of digestions are shown in Table I.

TABLE I

FIVE SERIES OF SLUDGE DIGESTION BOTTLES TO WHICH VARIOUS ACIDS WERE ADDED

Series	Control Bottle	Acetic Acid Bottle	Butyric Acid Bottle	Formic Acid Bottle	Lactic Acid Bottle	Oxalic Acid Bottle	Sulphuric Acid Bottle
			Grams of Acid Added to Each Bottle				
1	...	...	10.80	21.00	2.61	17.20	1.42
2	...	15.48	...	11.37	3.69	4.05	4.11
3	...	24.30	30.57	35.50	37.80	39.60	1.71
4	...	26.40	21.56	23.50	37.35	35.10	7.11
5	...	22.80	7.92	39.10	3.60	10.58	0.49
Total	...	111.3*	89.8*	130.47	85.05	106.53	14.84
			Cubic Centimeters of Gas Produced per Gram of Organic Matter in Sludge				
1	513	...	1076	650	400	579	149
2	212	425	...	262	112	120	161
3	206	299	639	474	250	369	43
4	151	165	363	218	304	263	169
5	54	313	117	421	36	137	30
Average	228	301	549	405	221	294	110
			Average pH During Digestion Period				
1	6.4	...	5.8	6.0	5.6	5.8	5.6
2	6.4	5.7	...	5.9	5.7	6.0	5.8
3	6.3	5.8	5.6	5.4	5.4	5.8	5.5
4	6.3	5.9	5.5	5.9	5.6	6.1	5.6
5	6.0	5.8	5.4	5.8	5.6	5.5	5.8
Average	6.3	5.8	5.6	5.8	5.6	5.8	5.7

* Calculated to the basis of five bottles.

Analyses were made but no particular study was made of the composition of the gas formed. The early stages of digestion gave the usual normal gas consisting of 20 to 25 per cent carbon dioxide and 65 to 75 per cent methane. In the later stages of digestion when the greatest amounts of acid were being destroyed, the carbon dioxide was from 40 to 70 per cent of the volume, with a corresponding decrease in methane. No hydrogen was found in any of the earlier fermentations so this determination was not regularly made. Toward the end of these experiments a few further tests were made for hydrogen but with negative results.

The pH of the sludge in all bottles before acid was added was well above 6.0. This was reduced to about 5.2 in two or three days by the addition of normal acid. This acid was destroyed gradually for the first week or so and then much more rapidly. Digestions were usually com-

plete in from four to six weeks. As the acid was destroyed, the pH increased, frequently from 5.0 to 6.2 or so in twenty-four hours, this change representing the disappearance of 40 cubic centimeters of normal acid. It was impossible on account of this rapid change to maintain any definite pH. Each day enough acid was added to reduce the pH to 4.8, 5.0 or 5.2. The value of stirring the sludge, even though no fresh solids were added, was shown frequently toward the end of digestion by the renewal of fermentation after it had apparently ceased.

Of course the gas from the bottles containing the acidified sludge resulted partly from the decomposition of the organic matter of the sludge and partly from the decomposition of the added acid. In the later stages of the fermentations, most of the gas undoubtedly came from the acid. Fermentations in the organic acid sludges were always more prolonged than in the control sludge, hence it seems likely that some constituents of the sludge entered into the later fermentation as otherwise the acids might have been fermented for an indefinite period after the fermentation of the sludge ceased. The volumes of gas formed were not proportional to the amounts of the acids destroyed, indicating that in some digestions more sludge was destroyed than in others.

An inspection of the tables shows that the sludge with added lactic acid produced the smallest amount of gas of any except that with added sulphuric acid, and that the amount of lactic acid destroyed was also the least of the organic acids. In two of the series, however, relatively large amounts of lactic acid were destroyed, but much more slowly at first than was the case with the other acids. All of our results showed that lactic acid is the least readily attacked by the bacteria of digesting sludge of any of the organic acids tested, but that under certain conditions the bacteria may slowly become accustomed to this acid and will then ferment it readily. Sulphuric acid was included merely to have a mineral acid for comparison. Free mineral acids are injurious to all bacterial action and of course such acids would rarely or never be found in sludge. In two of the sludges acidified with sulphuric acid considerable acid was reduced with the formation of hydrogen sulphide, requiring frequent addition of acid to maintain the pH at around 5.2.

It was evident from our results that organic acids as such are not necessarily injurious to actively fermenting sludge, but that their presence at the beginning of fermentation is harmful especially if in sufficient amount to reduce the pH to around 5.0 or less. This is shown by the results of a series of digestion experiments consisting of a control and four others, the pH of these being reduced initially with acetic acid to 4.8, 5.0, 5.2 and 5.4, respectively, and maintained as nearly as possible at these figures for a number of weeks.

The amounts of gas produced in these bottles are given in Table II.

TABLE II

pH of Sludge Bottle	Cubic Centimeters of Gas per Gram of Organic Matter	
6.4 (Control)	157	
4.8	0	
5.0	18	
5.2	224	
5.4	184	66

The bottle with a pH of 5.0 showed little fermentation and that kept at 4.8, none. When the pH was kept at 5.2, however, there was active fermentation and it is apparent from this that there is a sharp limit to the amount of acid in the sludge which will stop fermentation or permit it to occur. When fermentation is active, however, the pH can be reduced repeatedly to 4.8 or 5.0 without ill effects as was shown frequently during the progress of this work.

Effect of Iron Compounds on Sedimentation, Digestion and Ripe Sludge Conditioning[1]

BY WILLEM RUDOLFS,[2] LLOYD R. SETTER[3] AND WM. H. BAUMGARTNER[3]

INTRODUCTION

During the last few years experiments pertaining to the effect of iron salts and iron compounds upon different phases of sewage treatment have been conducted in our laboratory. Those dealing with theoretical considerations have been financed by a grant from the Chemical Foundation, Incorporated, and those dealing with the practical application of certain definite compounds under a fellowship established by the National Aluminate Corporation.

Sedimentation of sewage solids is at present practiced in settling tanks where the sewage is retained for a definite length of time and the solids are settled under more or less quiescent conditions. The sludge is removed at intervals either by gravity or pumping. Mechanical means for the gentle stirring of sewage and removal of the sludge from flat bottom tanks by scraping may conceivably aid settling and help in concentrating the sludge.

Chemical means for the removal of suspended particles have been used in the past in numerous cases and are still employed in isolated instances. The objection to chemical precipitation has been particularly the large quantity of sludge produced.

Occasionally there appears in the literature of recent years information dealing with the effect of iron compounds on the digestion of sewage solids. In cases where the iron content is comparatively low the beneficial effect has been ascribed to the possibility of iron catalysts. The evidence of this belief is, however, based largely upon laboratory experiments and upon the behavior of digestion tanks receiving industrial wastes, such as steel pickling liquors, which have a high iron content.

The effect of iron compounds, especially chlorinated copperas and iron chloride, upon the filtrability of activated sludge is now well known. No results from experiments seem to be available which show the effect of iron compounds upon the rate of drainage of fresh sewage solids and ripe sludge.

Effect on Sedimentation

Certain iron salts, especially iron sulfate, have long been used for precipitation of suspended solids in water treatment processes and to assist

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the sedimentation of sewage solids. Comparison of a number of precipitants and coagulants have been and are being made in our laboratories in an effort to study their effect upon the rate of settling of finely-divided suspended solids and the quantities of solids removed under controlled conditions.

Normally from 50 to 60 per cent of the suspended solids in sewage are removed by quiescent settling for one to two hours. With mechanical devices now in use the time required might possibly be reduced. However, even with the most efficient sedimentation devices comparatively large sedimentation tanks are required. The object of our studies is not so much chemical precipitation, which requires rather large quantities of chemicals, but a flocking-out process which possibly can be accomplished with small amounts of chemicals.

EXPERIMENTAL

One of the promising iron compounds used is ferric chloride ($FeCl_3$). Quantities ranging from zero to 15 p. p. m. were added to raw screened sewage. The results under discussion were obtained at Plainfield, N. J., by collecting samples through three different days, adding ferric chloride and determining the rate of settling after 1, 2, 3, 5, 7, 10, 12, 15, 20 and 30 minutes, by analyses to show the removal of suspended solids. The average results obtained are given in Figure 1. For each addition of ferric chloride a check was run so that the number of checks was greater than the number of samples treated, but each point on the curves represents an average of at least three samples.

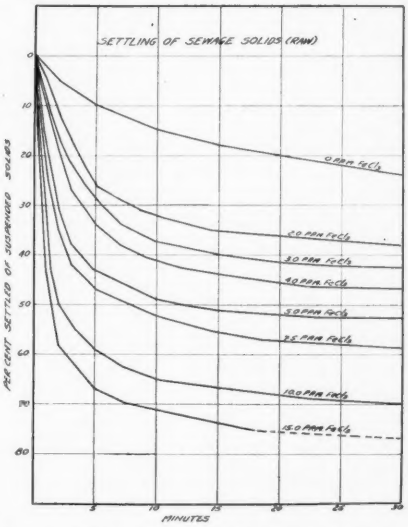


FIG. 1.—Effect of ferric chloride solution upon the settling of suspended solids in raw sewage.

The curves show that without treatment the percentage of suspended solids settled after 30 minutes was about 24%, with 2 p. p. m. $FeCl_3$, 38% with 5 p. p. m. 53%. After 10 minutes sedimentation time the percentage settled without treatment was 14.5, with 2 p. p. m. 32%, with 5 p. p. m. 49% and with 10 p. p. m. 65%. It can be seen that after 10 minutes or less sedimentation time, the removal curve flattens out for all

additions of $FeCl_3$ of 5 p. p. m. and over. Obviously the $FeCl_3$ has a certain effect which is felt very shortly after application, and the rate of settling thereafter does not proceed faster than with untreated material. It seems possible that with 5 p. p. m. $FeCl_3$ the sedimentation time might be cut in half or perhaps to only one-third of that for untreated sewage. If, however, the detention time in a tank is long, the effect of the chemical tends to disappear. This is best illustrated by a few figures obtained from plant scale experiments. With an estimated detention period of from 45 minutes to $1^1/_2$ hours the daily average suspended solids removal (samples every half hour), was, without treatment, 53.4 per cent and with treatment 59.4 per cent. In another case the daily average results were 51 per cent without and 51.8 with treatment. However, if the percentage removal is plotted for the different hours of the day, the greater part of the curve for the treated sample lies above that for the untreated. A large dip in the treated curve and a large rise at one point in the untreated curve destroys the difference in the average daily removal figures. There is no doubt that, even with these longer detention periods the removal of finely divided particles, which will not settle without treatment, is considerable, as evidenced by the clearer effluent. This statement is borne out by a study of the reduction in biochemical oxygen demand. For a morning run there was a percentage decrease in B. O. D. of 44 without treatment and 56 with treatment. Another average daily run showed 51.5% reduction of B. O. D. with treatment. This is considerably above the average result obtained without treatment over a long period.

Effect of Digestion

A considerable number of sewage disposal plants in this country receive trade wastes containing comparatively large quantities of iron. For example the Trenton, N. J., sewage disposal plant receives, among other trade wastes, quantities of steel pickling liquors. Shortly after the Trenton plant was put into service some experiments were made in order to find the difference in behavior, if any, of the sludge received at Trenton with that obtained at the Plainfield, N. J., plant, which receives domestic sewage.

The composition of the fresh solids obtained was as follows:

%	Trenton	Plainfield
Solids	4.35	4.98
Ash[1]	35.0	23.2
Iron as Fe[1]	10.11	4.20
Sulphates[1]	5.06	1.40
Chlorides[1]	0.23	0.34
pH	6.4	6.2

[1] On dry solids basis.

The fresh solids were incubated at 80° F. without seeding, and the

gases collected. The daily gas production per gram of volatile matter originally present is given in Figure 2. The curve showing the daily gas production from the Trenton solids is essentially the same as the curve for the daily gas production from the Plainfield solids. However, it required only 14 days for the Trenton solids to reach the peak of gasification, whereas it took the Plainfield solids 165 days before the gas peak was reached. The fresh solids collected at Trenton were three days old when incubated as compared with one day for the Plainfield solids. The total gas production was much greater from the Plainfield solids than from

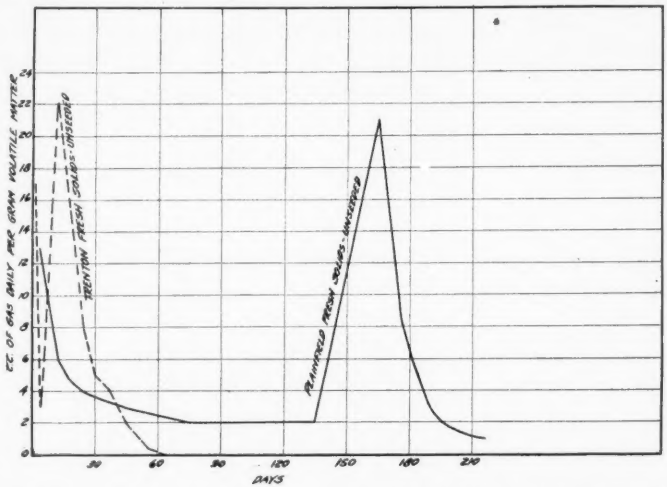


FIG. 2.—Daily gas production from solids containing iron wastes (Trenton) and domestic sewage solids (Plainfield).

the Trenton solids. The former produced 640 cc. per gram volatile matter and the latter 383 cc. Gas production from Trenton solids was completed after 60 days, whereas it took about 200 days for the Plainfield solids. The reduction of solids was correspondingly greater with the Plainfield material, namely 46 per cent against 26 per cent of the Trenton material.

Another batch of fresh solids collected at Trenton was seeded with ripe sludge obtained from a separate sludge digestion tank at Plainfield and compared with seeded fresh solids from that place. The mixtures used are given in Table I.

TABLE I

	Trenton		Plainfield	
	Solids %	Ash %	Solids %	Ash %
Fresh solids	4.35	34.9	6.00	20.1
Ripe sludge	5.48	49.9	7.42	50.7
Mixture	4.99	44.8	6.80	34.7

The gas produced per day per gram volatile matter over a period of 40 days is plotted in Figure 3, together with the cumulative gas production curve. The Trenton sludge reached its peak between the 16th and 17th day and the Plainfield material at the 22nd day of incubation. Gas production of the Trenton material was practically completed when the Plainfield material reached its peak. The cumulative gas curves show that although digestion was slower with the Plainfield material the total gas production during the first 20 days was almost the same in both cases. The total gas production per gram volatile matter was in this case again greater for the Plainfield domestic solids.

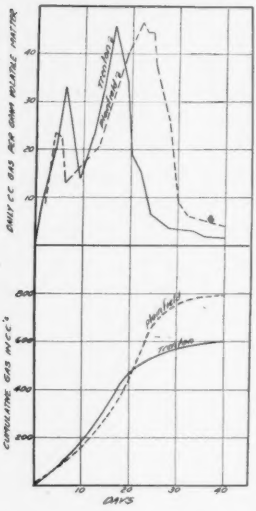


FIG. 3.—Gas production from seeded Trenton and Plainfield solids.

Reductions of solids and volatile matter are shown in Table II.

The amounts of gas produced per gram volatile matter destroyed during digestion was, for Trenton material, 1006 cc. and for Plainfield material, 1910 cc.

Since the heat value of the gas depends upon the quantity of combustible gases, it is of interest to show the composition of the gas (Figure 4) produced from the Trenton material. The gas had the usual composition found for Plainfield solids. The total quantity of CO_2 and combustible gas produced per gram volatile matter added was 130 cc. and 367 cc., respectively. The heat value of the gas was approximately 700 B. T. U. per cubic foot.

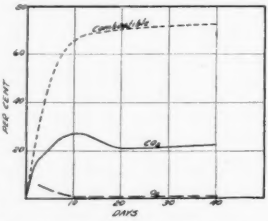


FIG. 4.—Composition of gas from Trenton solids.

TABLE II

REDUCTION OF SOLIDS AND VOLATILE MATTER

	Trenton					Plainfield				
	Solids	V. M.	Red. Solids	Red. V. M.	Red. V. M. added[1]	Solids	V. M.	Red. Solids	Red. V. M.	Red. V. M. Added[1]
Begin	4.99	2.74	..	..	..	6.80	4.44	..	..	..
End	4.07	1.97	18.4	32.0	63	4.81	2.59	29.1	41.7	82

[1] Assuming no further destruction of volatile matter.

Still another batch of fresh solids was collected from both places and this time seeded with ripe sludge from the plant where collected. The results

obtained were essentially similar to those reported above. Since this experiment was more elaborate and conducted for several other reasons it will be reported later; the important fact is that it checked the conclusions drawn before.

Addition of Iron Salts

A. Ferrous Sulfate.

Fresh solids collected at the Plainfield plant were seeded with ripe sludge and different quantities of ferrous sulphate were added. The mixtures were incubated at about 70° F. Comparisons of only one mixture to which this iron salt was added, with the untreated mixture will be made here. The composition of the mixture was as follows:

	Solids[1]	Ash[2]
Ripe sludge	6.90	45.1
Fresh solids	5.17	20.5
Mixture	6.45	35.4

[1] Wet basis.
[2] Dry basis.

To the mixture under consideration was added 26 grams ferrous sulphate per liter fresh solids.

Some of the results are shown graphically in Figure 5. The percentage reduction of volatile matter in the mixture containing iron sulphate was greater during the first part of digestion, but less at the end of 35 days than the percentage reduction of volatile matter in the untreated mixture. At the end of 60 days the percentage reduction of volatile matter was: untreated 46.2, treated 44.7, or as could be expected, only slightly higher than after 35 days, when digestion was, for practical purposes, completed.

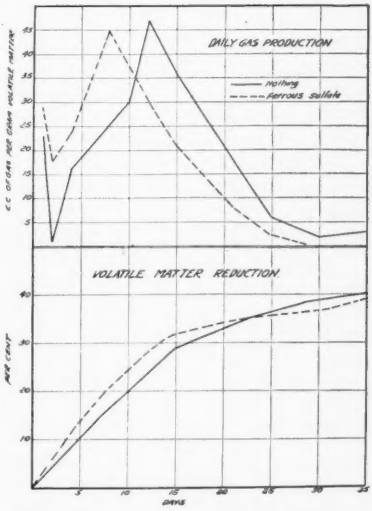


FIG. 5.—Effect of large additions of ferrous sulfate on gas production and volatile matter reduction.

The gas production curves show that the peak was reached with the treated material several days before the peak of the untreated mixture occurred.

B. Ferric Chloride.

The ferric chloride used in these experiments was a commercial product

containing 23.5% $FeCl_3$. The solution of ferric chloride was added to the sludge mixture in p. p. m. based on the volume of raw sewage. It was assumed that the settleable solids amounted to 150 p. p. m. The average total suspended solids in Plainfield sewage are about 220 p. p. m.; when this sewage is treated with 5 p. p. m. $FeCl_3$ about 150 p. p. m. settle in a given time. In one series quantities of from 1 to 20 p. p. m. $FeCl_3$ were added. The materials used showed on analyses:

	Solids[1] %	Ash[2] %	pH
Fresh solids	5.03	21.2	5.8
Ripe sludge	7.30	50.5	7.2
Mixture	5.80	35.4	6.8

[1] Wet basis.
[2] Dry basis.

Digestion was retarded, but more gas was produced at the end of the digestion time from mixtures to which from 5 to 20 p. p. m. $FeCl_3$ was added (Figure 6), but 1 to 4 p. p. m. $FeCl_3$ had no appreciable effect. The percentage reductions of solids and volatile matter were approximately the same for treatments up to 15 p. p. m.

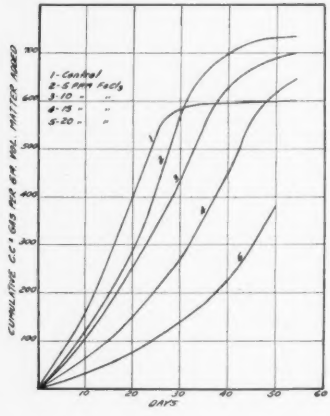


FIG. 6.—Effect of ferric chloride on gas production.

The acidity of the $FeCl_3$ caused a lowering of the pH values of the mixtures. The reaction changes were not great, but it took the material to which up to 10 p. p. m. $FeCl_3$ was added about a week to attain the pH values of the control; with 15 p. p. m. $FeCl_3$ 2 weeks, and with 20 p. p. m. 3 weeks. At the end of the experiment (54 days), the reaction was the same in all cases.

It appeared that the reaction changes caused by the addition of $FeCl_3$ might be related to the retardation of digestion, consequently another series was incubated in which the reaction was controlled with hydrated lime at the beginning of the experiment. The treatment given is shown in Table III.

The results showed practically no difference in gasification with additions of 2, 5 and 7.5 p. p. m. $FeCl_3$, but there were several days of retardation when the salt was increased to 20 p. p. m., and the digestion time was doubled with such large quantities as 40 p. p. m. The reduction of solids was the same in all instances except the last.

TABLE III
QUANTITIES OF LIME ADDED

$FeCl_3$ Added p. p. m.	Lime Added Grams[1]	pH before Liming	pH after Liming
1	1.05	6.8	7.2
2	1.33	6.4	7.2
5	1.48	6.1	7.4
7.5	1.61	6.1	7.4
20	2.25	5.9	7.3
40	3.40	5.5	7.2

[1] Grams lime per liter fresh solids.

These large quantities were added only for theoretical considerations. Since it is not necessary to add more than 4–5 p. p. m. to the raw sewage in order to obtain improved settling, the effect of additions of 5 p. p. m. or less are of greater practical interest.

The most interesting experiments were those conducted with sludge that had settled in the sedimentation tank when iron chloride was added to the raw sewage. A series of digestion experiments conducted with fresh solids settled from sewage to which 5 p. p. m. iron chloride was added showed that the *rate* of gasification was considerably increased as compared with the gas production from fresh solids settled from untreated sewage. The effect of iron chloride was also evidenced by the *smaller total quantities* of gas produced. The treated and untreated sludge was seeded with the same ripe sludge in a ratio of 2 : 1 on the volatile matter basis. Mixtures were incubated at 70° F. The treated solids were collected during the daytime and the untreated solids during the same hours on the next day. Although these two batches of fresh solids are not strictly comparable the differences obtained were sufficiently striking to warrant definite conclusions.

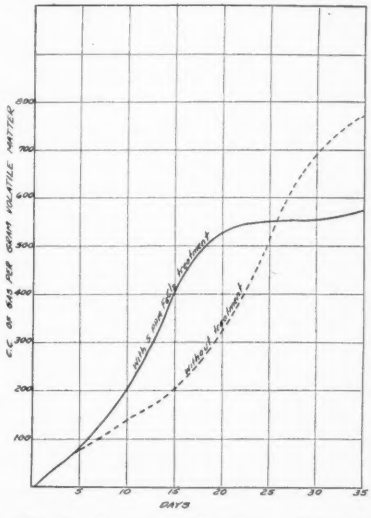


FIG. 7.—Gas production from solids settled from sewage treated with 5 p. p. m. $FeCl_3$ as compared with untreated sewage.

Figure 7 shows the cumulative gas production of the two mixtures. The digestion of fresh solids collected from the sewage treated with $FeCl_3$ was rapid. The gas peak occurred in 16 days and the digestion was practically completed in

20 days. The gas peak of the untreated solids collected the next day occurred considerably later and the total digestion time was 32–35 days, or approximately similar to a great number of mixtures experimented with in the laboratory. Although gas production was more rapid and the digestion time reduced under the treatment the amount of gas produced was considerably less. The difference amounted to 200 cc. gas per gram volatile matter.

C. Other Iron Compounds.

Another set of experiments was conducted with addition of Fe, $(Fe(OH)_3$, Fe_2O_3, $FeCl_2$, $FeCl_3$, $FeSO_4$, $Fe_2(SO_4)_3$, iron acetate and iron citrate. The results will be reported elsewhere in detail. The results show that, depending upon the type of iron compounds, the effect upon gasification and reduction of volatile matter may cause: (*a*) retardation, (*b*) stimulation or (*c*) have no effect whatsoever. Retardation might be caused either by:

A. The toxicity of the iron compounds.

B. The increased acidity resulting from the iron treatment.

Stimulation of digestion activities seems to be related to:

A. The chemical structure of the iron compound.

B. The type and possibly the degree of dissociation of the iron compound.

Effect on Sludge Drying

It is well known that ferric chloride added to activated sludge causes the sludge to give up its water more easily and rapidly. It is not the intention of this paper to present a discussion of the reasons for the more rapid drying, nor to give data pertaining to the filtrability of activated sludge, but only to present results obtained on the time required for filtration of digested sludge to which different amounts of ferric chloride were added. Some of the experiments were on a plant scale. The procedure followed the usual method for determination of filtering time, using given quantities of sludge, draining the water by suction and recording the filtering time in minutes. The filtration tests were made using 100 cc. of conditioned sludge upon low ash American Standard filter papers in 8 cm. diameter Büchner funnels. The moisture content of the sludge used was in all cases 92.7 per cent. The filtered liquid was measured and the moisture of the sludge cake determined. Figure 8 shows the effect of different quantities of salt (expressed in pounds ferric chloride per cubic yard of sludge) on the rate of filtering of ripe sludge. It is evident that even comparatively small quantities of $FeCl_3$ solution increase rapidly the rate of drainage. With 0.5 pound $FeCl_3$ per cubic yard the same percentage removal of water can be obtained in 4 minutes as is obtained in 14 minutes when nothing is added. The required time is reduced to $1^1/_4$ minutes with 2 pounds $FeCl_3$.

Filtered ripe sludge with a moisture content of 75 per cent is spadable and can be handled easily. Further moisture removal becomes increasingly difficult. With the material used in these tests the maximum dryness of the cake in a constant filtering time of 14 minutes was slightly above 70 per cent. The effect of increasing quantities of $FeCl_3$ solution on the moisture removal is demonstrated in Figure 9. With two pounds $FeCl_3$

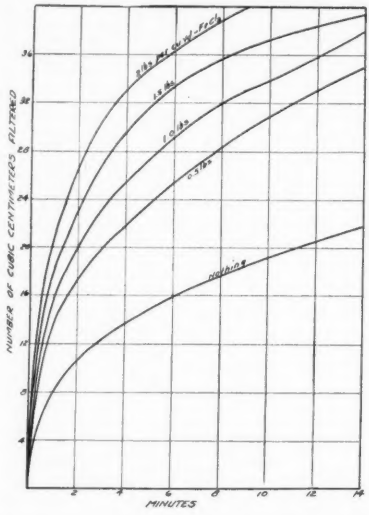


FIG. 8.—Effect of ferric chloride on filtering time of ripe sludge.

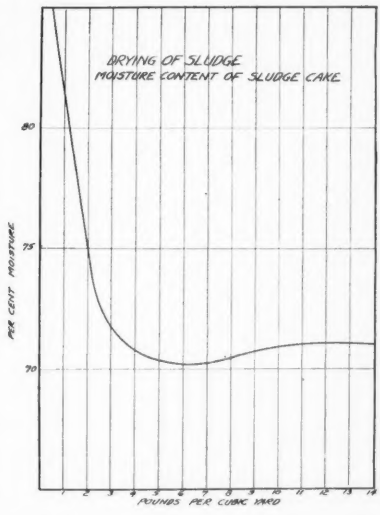


FIG. 9.—Effect of increasing quantities of $FeCl_3$ on water removed from ripe sludge.

solution the moisture content of the cake amounted to 75 per cent. The minimum moisture content was obtained with 6 pounds $FeCl_3$ per cu. yd. of sludge. Larger quantities of iron chloride did not decrease the moisture content further but caused it to increase.

The action of ferric chloride on sludge, causing this increase in the rate of dewatering, is practically instantaneous. With increased amounts of $FeCl_3$ the sludge drains with increasing rapidity. The optimum condition appeared to be at pH 6.4, which is very much higher than found by Mohlman and Palmer[4] for activated sludge. They found the optimum to be pH 4.3. From a detailed study it appears that there is a more or less definite relation between pH values and time of filtration, the pH values indicating the changes taking place in the material. One set of detailed results is shown in Figure 10. It is evident that changes take place in the sludge material at pH 7.4, 7.0, 6.4, 6.0 and 5.8, probably due

[4] Mohlman and Palmer, *Eng. News-Rec.*, Jan. 26, 1928.

to the coagulation of different substances in the sludge. A more detailed discussion of the phenomena involved will be published later.

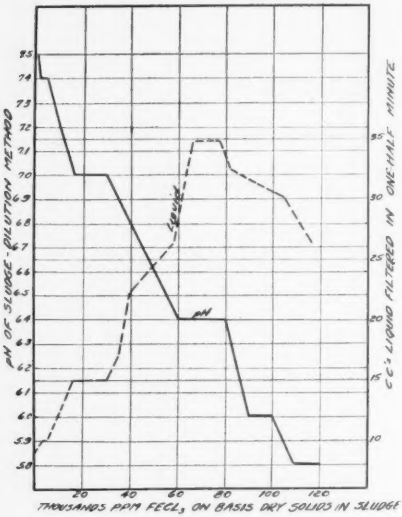


FIG. 10.—Relation between pH values and water removal from ripe sludge.

Drying on Beds

Field experiments conducted during February, 1929, when shortly after sludge drawing about four inches of snow fell on the beds, give an indication of what happened. This is graphically shown in Figure 11.

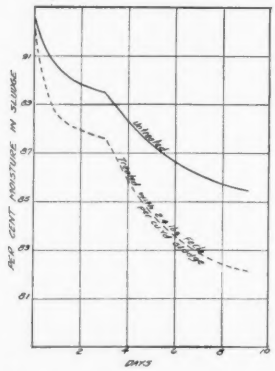


FIG. 11.—Moisture content of sludge on drying beds.

The bed receiving the untreated sludge was filled to a depth of 9 inches, whereas the bed filled with treated sludge received 12 inches of sludge. In comparing the moisture contents of the materials on the two beds this should be kept in mind.

In spite of the fact that snow covered the treated sludge the moisture content of the sludge had been reduced from 92.4 per cent to 82.2 whereas the moisture content of the untreated sludge was still 85.5 per cent after 9 days. Other trials show that the moisture content of untreated sludge increases after a rain, whereas the moisture content of treated sludge does not increase, indicating that the texture of the sludge is changed in such a way that the water is not absorbed but is repelled by the treated sludge.

DISCUSSION

The results presented in this paper are necessarily but part of the data obtained. They seem to show that iron salts in general, and ferric chloride in particular, play an important rôle in sewage treatment.

The more rapid separation of suspended solids from the raw sewage liquid would be particularly advantageous at existing plants where the

percentage removal is low on account of inadequate detention, and probably also at those places where the sewage has to travel comparatively long distances and the particles are disintegrated so that the finely comminuted particles settle with great difficulty. The same considerations hold for those sewages containing certain trade wastes rich in colloidal substances, for example, dairy and creamery wastes.

An even more important use of ferric chloride might be made in those cases where no secondary treatment is given and the effluent must be temporarily improved; for instance, during summer time when the flow of the receiving stream is low, or when secondary treatment is needed but not installed. In those cases the effluent from the sedimentation tank might be treated and the liquid put through a small secondary sedimentation tank.

In a number of instances secondary sedimentation tanks, following sprinkling filters, have a tendency to decrease the stability of the effluent from the filters, due either to finely divided material passing through or to the decomposition of the sludge coming from the beds. Often such secondary sedimentation tanks are really functioning only during sloughing periods, which might not be more than three months out of the year. Treatment of the bed effluent would in those cases help greatly. Again, at other places a still higher purification might be required than is possible with sedimentation tanks, sprinkling filters and secondary treatment tanks and changes of the existing plant to activated sludge too costly. Here, ferric chloride treatment would help considerably and could be effected at comparatively low cost.

At activated sludge installations it sometimes happens that finely divided material leaves the final settling tanks. Although the actual weight of these suspended solids is low and they not greatly affect the character of the effluent it is desirable to retain them in the settling tank in order to obtain a perfectly clear effluent. The addition of small quantities of ferric chloride would be of decided advantage.

The effect of iron compounds on digestion is of specific interest to those plants receiving iron wastes. In this connection it is very interesting to find that small quantities of ferric chloride added to raw sewage affects the decomposition processes in a similar and almost identical way as the iron compounds received from industries. In this respect attention is called to the results obtained with ferric chloride when added to raw sewage, as compared with the results obtained with sludge from the Trenton plant. In both cases gasification was much more rapid and the digestion time shorter than with untreated materials. However, the total quantities of gas produced were less and the percentage reduction in volatile solids was only half as great in the sludges containing iron.

The problem of sludge drying is important. During the last few years

means have been found and applied to reduce the digestion time and subsequently the digestion capacity required. In order to make full use of the knowledge obtained we should be able to dry the ripe sludge in winter as well as in summer. With the aid of ferric chloride the drying time might be reduced considerably, but this decrease in time is by no means sufficient to solve the problem. Until a method is found, which will probably consist of a combination of chemical and mechanical means, whereby the sludge can be dried almost as rapidly as drawn from the tanks, the problem will be with us, especially at the larger plants. Smaller plants which have almost enough drying bed capacity, but are frequently held up in the regular drawing of sludge, can benefit by adding comparatively small quantities of ferric chloride to the ripe sludge. It is of interest to note that poorly digested sludge, which causes most of the delay in drying, will dry much more quickly when ferric chloride solution is added. In this respect it should be emphasized that too much stirring of sludge with the chemical is detrimental to the drainage. The floc, which is almost instantaneously formed, breaks up with the result that most of the benefit is lost. It must be remembered also that the formation of the floc causes the sludge to float and drainage becomes more rapid, whereas with too much stirring the sludge sinks to the bottom leaving a sheet of water on top which retards drying.

CONCLUSIONS

Experiments conducted with different iron compounds to learn something more about their effect upon settling, digestion and drying of sewage solids show that:

1. The rate of settling of sewage solids is greatly increased with quantities of ferric chloride as small as 5 p. p. m. or less.
2. Different iron compounds affect digestion differently; some are helpful, others detrimental and still others have no effect.
3. Large quantities of ferrous sulfate are beneficial; small quantities of ferric chloride increase the rate of gas production, reduce the digestion time, but decrease the total quantity of gas produced.
4. Drying of digested sludge is accelerated by the addition of ferric chloride.

The Biology of a Sewage Treatment Plant— A Preliminary Survey— Decatur, Illinois

BY H. P. K. AGERSBORG[1] AND W. D. HATFIELD[2]

Sewage purification is recognized as a combination of physical and biological phenomena, which effect sedimentation, coagulation, reduction and oxidation. The latter three processes are largely the result of the metabolism of many types of micro-organisms. In all probability bacteria play the most important part in sewage treatment, but any form of plant or animal that derives its food supply directly or indirectly from the organic matter in the sewage undoubtedly participates in the total purification.

Although a large amount of work has been done on the bacteriology of sewage treatment, very little fundamental data have been produced because of the lack of proper media and technique, particularly in anaerobic culture studies. Numerous investigators[2,3,4,5,6] have studied the protozoan life in Imhoff tanks, sludge digestion tanks and sprinkling filters. A few[1,7,8,13] have reported on the biology of the activated sludge process. Whether the protozoa aid in digestion and purification or whether their presence is an indication of the condition of the digestion processes is not fully established. However, as indicator organisms they may prove a great aid in operation of a treatment plant, supplementing if not supplanting some of the chemical analyses.

Due to the large quantity of industrial sewage at Decatur[9] and to the fact that the sewage plant comprises Imhoff tanks and partial aeration (pre-aeration)[9] followed by sprinkling filters, a biological study of the plant promised to be most interesting. Such a survey[7] was made during June, July and August, 1928.* In so short a time the work can be only of a preliminary nature, and therefore the data are presented with that restriction in mind.

The Sewage Treatment Plant

The sewage of the city of Decatur consists of about 6 million gallons per day of domestic sewage, including the normal industrial wastes in a city of 58,000 inhabitants, and 4 million gallons per day of waste from a cornstarch and glucose plant. The total industrial and human population equivalent (based on the factor 0.17 lb. 5-day B. O. D. per capita) in 1926 was about 350,000, but was reduced to a total of 125,000 early in 1928 by recoveries of the waste as by-products within the industrial plant.

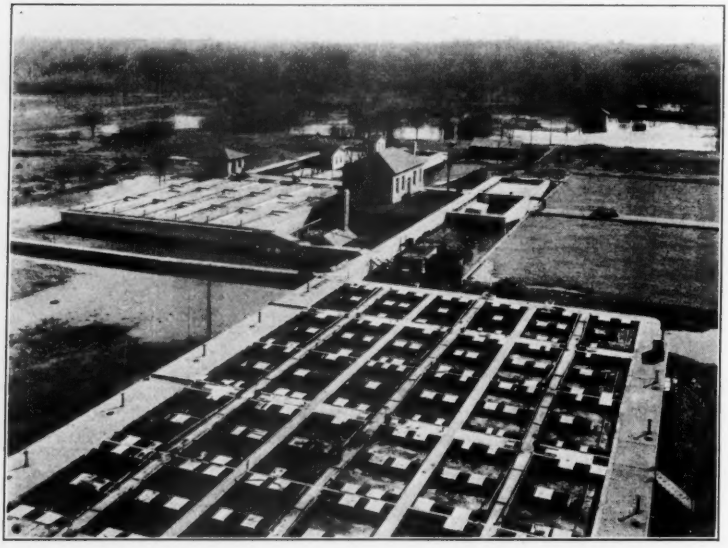
[1] *Special Biologist, Sanitary District of Decatur.*

[2] *Supt., Sanitary District of Decatur.*

* The Illinois State Water Survey furnished the salary of the biologist for this work.

The sewage treatment plant is designed for an estimated population equivalent of 150,000 of mixed sewage and industrial waste. The capacities with a dry weather flow of 10 M. G. D. are as follows:

Imhoff Tanks—detention period	1.0 hour
sludge capacity	3.03 cu. ft./cap.
Aeration—without re-aeration of sludge	2.5 hours
Aeration—with re-aeration of sludge	1.67 hour
sludge re-aeration	9 to 18 hours
Sprinkling Filters	3.0 acres, 6 ft. deep
Rate	3.3 M. G. A. D.
Secondary Settling Tank, detention period	30 minutes



Imhoff tanks, pre-aeration plant, dosing tanks and sprinkling filters, and experimental plant. Secondary tank in background—under water because of high river.

The efficiencies of the plant during June, July and August, 1928, are indicated in Table I.

The crude sewage received at the plant (except during times of storms) contained from 180 to 280 p. p. m. suspended matter and from 3 to 4 cc. per liter of settleable matter in one hour's settling. The average 5-day B. O. D. was 236 p. p. m.; the total nitrogen about 25 p. p. m., of which 10 to 15 p. p. m. was free ammonia nitrogen; sulfur dioxide from the starch waste, 48 p. p. m.; pH, 6.2; dextrose about 8 p. p. m.

TABLE I

OPERATION RESULTS, DECATUR TREATMENT PLANT, JUNE, JULY AND AUGUST, 1928

	Suspended Matter			B. O. D. (5-day)		
	June	July	Aug.	June	July	Aug.
Crude Sewage, p. p. m.	270.0	183.0	180.0	281.0	210.0	218.0
Per Cent Removal by*						
Imhoff Tanks	68.8	55.1	60.0	22.6	34.0	31.3
Pre-aeration	61.0	45.1	50.0	53.8	54.7	54.1
Sprinkling Filters	66.6	70.5	62.8	86.5	90.9	89.5
Secondary Tanks	..	..	72.3	..	..	90.8

	Final Effluent		
	June	July	Aug.
Per Cent Stability	84.0	98.0	97.0
Nitrate Nitrogen	11.0	11.0	12.8
Total Sewage Flow, M. G. D.	9.12	10.30	9.88

* The per cent removals are the total removal of all the processes to and including the effluent under consideration.

An estimate of some of the material introduced into the sewage by the starch waste may be obtained from the following average data:

STARCH WASTES

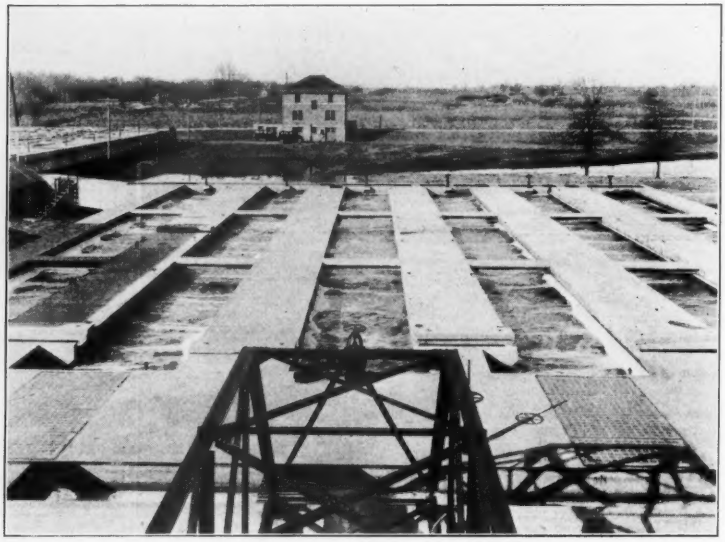
Total solids	30,000 lb. per day
Volatile solids	14,000 lb. per day
Total nitrogen	1,000 lb. per day
Sugar (dextrose)	670 lb. per day
Sulphur dioxide	4,000 lb. per day
B. O. D. (5-day)	12,500 lb. per day

Biological Studies

Sewage.—Due to the presence of the strong industrial waste it is not surprising to find a scarcity of life in the raw sewage. Microscopical examinations of the raw sewage revealed the constant presence of bacilli, cocci and the filamentous bacteria *Sphaerotilus natans*. Fungi, algae, protozoa and metazoa were not usually present except as encysted cells. On July 5, after the holiday shutdown of industry, the following organisms were found: bacilli, cocci, *Sphaerotilus natans*, *Oscillaria*, *Monas*, *Colpidium* (?) and dead *Opercularia*.

Imhoff Tanks.—In the sludge digestion chamber of the Imhoff tanks some of the encysted organisms are freed and a healthy protozoan flora builds up, which may be seen under the microscope devouring bacteria and amorphous matter of the sludge. A microscopic survey of sludge from the sludge digestion compartments of the six Imhoff tanks revealed that the individual tanks did not differ materially and that there was a characteristic change of flora from the bottom to the top of the tank.

A summary of this survey is given in Table II. The samples were collected by pumping from various depths and immediately examined under the microscope with low power, high power and oil immersion where necessary. The samples were taken at about two-foot intervals of elevation.



Office building, Imhoff tanks, aeration tanks.

Bacilli, cocci and *Sphaerotilus natans* were present at all elevations, with *Zoogloea ramingera* found only occasionally at the surface of the sludge. Three species of Vahlkampfia (a rhizopod related to amoeba) were usually present at all elevations, but were most numerous in the sludge. Small flagellates were present at all depths, but were more abundant at the sludge line or in the liquor just above the sludge line. In this region, where fresh organic matter is continuously being deposited, the greatest number of flagellates were found. A few ciliates were present in the sludge, but they occurred more abundantly in the liquor above the sludge. *Metopus sigmoides*, *Oxytricha* and *Colpidium* were almost always present in the liquor.

The hydrogen-ion concentration of the sludge liquor at different depths was determined colorimetrically and with the quinhydrone electrode. The latter gave pH values about 0.2 higher than were obtained with bromthymol-blue and recorded in Table II. This discrepancy was found to be due to the very rapid loss of CO_2 from the solution during the manipulation

TABLE II

MICROSCOPICAL SURVEY OF THE IMHOFF TANKS

Source of Samples	Bacteria				Algae				Protozoa: Rhizopoda							Protozoa: Flagellata										Protozoa: Ciliata										Metazoa		pH
	Bacilli	Cocci	*Sphaerotilus natans*	*Zoogloea ramigera*	Blue-green algae	*Trachiscia*	*Chlorosphaera*	*Richtericella globosa*	*Valkampfia gultula*	*V. limax*	*V. minuta (sp. nov.)*	*Pridamoeba primitiva*	*Harlmanella hyalina*	*Dimastigamoeba*	*Mastigella*	Encysted and free amoeba	*Bodo (sp.)*	*Bodo caudatus*	*Cercobodo*	*Oikomonas*	*Dinomonas vorax*	*Proxenema*	*Pelalomonas carcinata*	*Heteromita ovata*	*Heteronema ovus*	*Holophrya*	*Prorodon*	*Chaenia*	*Lionotus*	*Amphileptus* (sp.)	*Colpidium*	*Paramoecium*	*Metopus sigmoides*	*Caenomorpha*	*Strichotricha*	*Eschaurastyla brachytoma*	*Gastrostyla*	*Oxytricha*	*Operularia* (dead)	*Rhabdolaimus minor*	*Nematode*	pH to Brom-thymol blue
Bottom	x	x	x						x	x	x			x			x				x								x										7.5
5 to 8 ft. above bottom	x	x	x		x				x	x	x						x							x															7.6
9 to 11 ft. above bottom	x	x	x		x				x	x	x						x											x			x								7.6
13 to 14 ft. above bottom	x	x	x	x		x			x	x		x					x			x	x				x		x			x							x		6.8
15 to 17 ft. above bottom	x	x	x			x			x	x	x						x	x	x				x							x		x		x		x			6.7
19 to 21 ft. above bottom	x	x					x		x	x	x	x	x		x		x					x				x			x			x				x	x		6.8
23 to 29 ft. above bottom	x	x	x								x	x	x			x	x	(small flagellates)							x					x	x	x		x	x	x		x		6.8

NOTE: The sludge line in the six tanks varied from 12 to 13.5 ft. above the bottom.

of the quinhydrone electrode. A similar loss could be produced by handling the solution in the same manner and then adding the indicator. Therefore pH determinations on sludge liquor should be made as soon as possible on liquor pipetted from considerably below the surface of the sample bottles.

The Imhoff tank effluent contained very few protozoa, as would be expected from their absence in the influent sewage. Except for this feature, the results on the Decatur tanks are very similar to those reported by J. B. Lackey[5] for tanks operating normally and without foaming.

Pre-aeration Plant.— The pre-aeration plant operates similarly to an activated sludge plant except that the aeration period and quantity of air used are only about one-third to one-fourth that necessary for complete activated sludge treatment. This reduced aeration under Decatur conditions gives B. O. D. reductions of about 20 to 30 per cent and produces an under-aerated sludge which is brownish black, at times slightly septic, and only about 60 to 80 per cent of which will settle in the settling tanks. This bulking sludge has been a most interesting problem and if conditions can be made such that a better settling sludge can be obtained, the efficiencies of the process can be materially increased.

The organisms found in the aeration tanks from June 28 to July 9, 1928, are listed in Table III. This table is a summary of all organisms

TABLE III

ORGANISMS IN AERATION TANKS JUNE 28 TO JULY 9, 1928

Near Inlet End of Aeration Tanks

Higher Bacteria, Fungi, Algae	Protozoa	Metazoa
Bacilli, cocci	*Hartmanella hyalina*	*Rotifera*
Sphaerotilus natans	*Vahlkampfia albida*	
Zoogloea ramingera	Small flagellates	
	Bodo caudatus	
Filamentous algae	*Petalomonas*	
Binuclearia tetrana	*Dinomonas vorax*	
Trentipohlia	*Distigma proteus*	
Pandorina	*Chilodon cucullulus*	

Near Outlet End of Aeration Tanks

Bacilli, cocci	*Hartmanella hyalina*	Nematode
Sphaerotilus natans	*Protamoeba primitive*	(occasional)
Beggiatoa alba	*Vahlkampfia limax*	
Filamentous algae	*Vahlkampfia guttula*	
A blue-green algae	*Biomyxa*	
A green algae	*Bodo*	
	Bodo caudatus	
Diatoma	*Physomonas*	
Richteriella globosa	*Oikomonas*	
Phytogloea	*Cercomonas*	

TABLE III (*Continued*)

Higher Bacteria, Fungi, Algae	Protozoa	Metazoa
Palmodictyon (?)	*Petalomonas*	
Radiofilum	*Dinamonas vorax*	
Trentipohlia	*Monas*	
Oscillatoria prolifica	*Pleuramonas jaculans*	
Phytozoogloea	*Chilomonas*	
	Astasia	
	Rhabdostyla vernalis	
	Plagiopyla nasusta	
	Euglena	
	Blepharisma	
	Chilodon	
	Colpidium	
	Hexotricha	
	Bursaria	
	Metopus sigmoides	
	Oxytricha	
	Carchesium	
	Vorticella	

found in samples taken during this period. All organisms listed are not found in any one sample, therefore, the two parts of the table are not directly comparable. The samples, however, did consistently show a larger variety of organisms after the 2.5 hours of aeration. *Zoogloea ramingera* and *Sphaerotilus natans* are the most common inhabitants of the tanks with *Metopus sigmoides* omnipresent. The aeration favors an increase in the small flagellates, the hypotrichous and peritrichous ciliates. The flora and fauna are stimulated toward the more aerobic organisms.

Ardern[8] has summarized the protozoal characteristics of activated sludge as follows:

(*a*) "*Sludge in bad condition.* Preponderance of Flagellates, *Amoeba* (and other Rhizopods); relatively few Ciliates, *e. g., Carchesium, Chilodon, Choenia** absent."

(*b*) "*Sludge in unsatisfactory condition.* Flagellates and *Amoeba* (and other Rhizopods); some ciliates *e. g., Stentor, Paramoecium, Chilodon, Carchesium,* Vorticella; *Choenia* absent."

(*c*) "*Sludge in satisfactory condition.* Few Flagellates and Amoeba; preponderance of Ciliates, *e. g., Carchesium, Vorticella, Chilodon, Colpoda, Colpidium;* some *Aspidisca* and *Loxophyllum;* occasional *Choenia;* few Suctoria."

(*d*) "*Sludge in good condition.* Very few Flagellates; Amoeba are rare; preponderance of Ciliates, *e. g., Carchesium, Vorticella, Aspidisca, Loxophyllum, Choenia;* few Suctoria."

The sludge described in Table III would be judged as unsatisfactory

* *Chaenia* (in Ward and Whipple's "Fresh Water Biology").

according to this classification. This is to be expected from a plant designed for partial aeration unless sufficient reaeration of the sludge is given to keep the sludge entirely activated. A discussion of the biology of the sludge during reaeration will be published later. See also Agersborg (1929).[7]

During the time the studies reported in Table III were being made, there was very little sludge in the sludge liquor being returned to the aeration tanks. On one hour's settling of the aeration tank effluent there was only 2 or 3 cc. of sludge per liter even though at that time 2.0 M. G. D. (20%) of settled sludge from the settling tanks was being returned to the aeration tanks. The B. O. D. reduction due to pre-aeration at this time was 31 per cent. This reduction was very gratifying when the small amount of sludge in the process was considered. The return sludge was mostly water which on one hour's settling gave 8 to 10 cc. per liter of sludge. Immediately after a heavy rain a heavier brownish near-activated sludge would build up in the more dilute sewage. This sludge soon became infected with *Sphaerotilus*, bulking followed, and most of the sludge would be lost over the weirs of the settling tank to the sprinkling filters.

Morgan and Beck[11] have shown that heavy growths of *Sphaerotilus* caused bulking of the sludge and reduced efficiencies at the activated sludge plant of Maywood, Illinois, and that the trouble was caused by the presence of large quantities of sugar in the sewage from illicit stills. The Decatur sewage contains variable amounts of dextrose from the starch waste and in all probability this is the cause of both the *Sphaerotilus* growths, which are found all though the plant, and of the continuous bulking of the sludge.

The real problem in the operation of a pre-aeration plant is to reduce sludge bulking to a minimum. Even though a removal of 31 per cent B. O. D. by pre-aeration at Decatur is satisfactory and is about the efficiency expected from the testing station results[10] nevertheless if conditions could be established so that a better sludge could be produced the efficiencies of the plant could be increased and the total load on the plant increased above the 150,000 population for which it was designed. Therefore, some studies were made on the organisms in the aeration liquor under various conditions of aeration.

Experimental Pre-aeration Studies.—*1. Prolonged aeration at normal rate of agitation.*—The inlet and outlet valves of one of the aeration tanks were closed and the tank liquor allowed to aerate at the normal aeration rate (normal agitation) for 6 days. During these days samples were examined under the microscope. The results are summarized in Table IV. These data show that:

Sphaerotilus natans began to decrease after 4 hours aeration and continued to decrease until few were left on the 6th day.

A few amoeba were present but never in sufficient numbers to be significant. Some of them may have been flagellates in their amoeboid stage.

Small flagellates increased the first day and were very numerous on the 3rd day, then declined until almost absent on the 6th day.

The Chloroflagellates occurred in large numbers on the 3rd and 4th days but were gone the 5th day.

The peritrichous Ciliates increased gradually until on the 6th day they were very numerous. On the sixth day sewage was again turned into the tank. Within three to seven hours *S. natans* was on the increase, small flagellates were reappearing and *Vorticella* had developed the basal circle of cilia.

TABLE IV

ORGANISMS OBTAINED ON PROLONGED AERATION (NORMAL AGITATION)

Temperature of Sewage, 32 to 34° C.

Hours Aeration	Higher Bacteria, algae	Protozoa
0	*Beggiatoa arachnoidea*	*Oikomonas*
	Beggiatoa sp.	*Trachelomonas*
	S. natans	*Metopus sigmoides*
	Z. ramingera	
4–8 hrs.	Fewer *S. natans*	Increase in small flagellates
	Beggiatoa	Many small amoeba
	Z. ramingera	*Vahlkampfia albida*
		Amoeba radiosa
		A. limax
		Metopus sigmoides
		Vorticella, Opercularia
24–48 hrs.	*S. natans* moderate in number	*A. limax*
		Small flagellates
		Euglena
		Phacus
		Colpidium
		Metopus sigmoides
		Vorticella
		1 dead *Paramoecium*
48–54 hrs.	*S. natans* and other filamentous organisms becoming scarce	*A. limax*
		Large number of small flagellates
		Petalomonas irregularis
	Z. ramingera	*Anisonema*
	Gonium and *Pandorina* in large numbers	*Metopus sigmoides*
		Metopus sp.
	Eudornia	*Oxytricha*
	Spondyloniorum	*Vorticella telescopica*
	Spirillum major	*Vorticella Microstoma*

TABLE IV (*Continued*)

Hours Aeration	Higher Bacteria, algae	Protozoa
72 hrs.	Organisms about the same as 54-hour sample	
120 hrs.	*S. natans* (few) *Z. ramingera* (few) *Chloroflagellates* gone	*A. radiosa, A. limax* *Oikomonas* and many small flagellates *Chaenia, Colpidium, Colpoda, Paramoecium aurella* and *caudatum, Vorticella*
148 hrs.	Filamentous bacteria still present but not numerous	*Vorticella*, many *Opercularia* Other Ciliates missing
	SEWAGE FLOW INTO TANKS AGAIN	
3 hrs. later	*S. natans* on rapid increase	*A. limax, Astasia, Euglena* Clusters of *Vorticella*, 40 in a bunch
7 hrs. later	*S. natans*, many	*Metopus sigmoides, Vorticella*, some have a 2nd row of cilia

2. Prolonged Aeration with Greatly Increased Rate of Agitation.—A study similar to the above was made with about twice the normal agitation by aeration, to determine whether excessive agitation might not inhibit development of the protozoa. The results were similar to those in Table IV except that a larger number of Chloroflagellates occurred. The results showed conclusively that growth was not inhibited by even greatly increased agitation over that normally used in the Decatur tanks.

3. Prolonged Aeration with Greatly Decreased Agitation.—The effect of greatly decreased aeration was studied by closing the inlet air valves until only enough air was maintained to show a few bubbles through the aeration plates. The air meter read zero, but there was sufficient air passing to keep the aeration liquor rolling very gently. One tank was cut out of service for prolonged aeration similar to the above studies, while the other tank received sewage at the regular rate (2.5 hours detention period).

Specimens from the tanks were collected and examined after 24, 48, 72 and 96 hours. The samples showed little or no change in flora and fauna and are summarized as follows:

AFTER 96 HOURS OF AERATION WITH GREATLY REDUCED AGITATION

1st Tank	2nd Tank
Prolonged aeration	Continuous sewage flow
Bacteria	Bacteria
S. natans	*S. natans*
Zoogloea ramingera	*Z. ramingera*
Small Amoeba	*Z. globosa*
Small flagellates	*Beggiatoa*
One *Vorticella*	Small Amoeba

Sufficient air was not present in these experiments to maintain or even approximate an aerobic flora. In order to maintain a good sludge that settles rapidly and efficiently, it seems necessary to give the process longer aeration at a moderate (normal) rate of agitation. This might be accomplished by prolonged reaeration of the sludge.

Life in the Sprinkling Filter Effluent.—Time was not available to make a thorough study of the organisms on the stones of the filter beds. Noticeably present on the stones near the surface were various species of algae and fungi; rotifiers in large numbers and a variety of species; a few nematodes, water mites and fly larva. During the last week of June large numbers of *Opercularia plicatiles* and *Colpoda* were present.

The Decatur sprinkling filters operate at rather high temperatures all the year round so that there is not the periodic spring and fall sloughing-off of the slime, but instead a rather continuous sloughing. In Table V are reported seven examinations made of the organisms in the sprinkling filter effluent. These data show that the flora and fauna have changed on passing through the filter beds from that of rather typical sewage types to that more analogous to normal pond water. These data check fairly well with those of Frye and Becker[12] on an experimental sprinkling filter purifying diluted milk, even though these are effluent samples and theirs were samples of slime from the filter media. This difference probably explains the fewer number of species found at Decatur. As has already been indicated, a more thorough examination of the effluent would have disclosed a larger number of species. (Compare also with Agersborg (1929)[7].)

TABLE V

LIFE IN SPRINKLING FILTER EFFLUENT

Date	Bacteria and Algae	Protozoa	Metazoa
June 28	*Aeronemum polymorphum*	*Amoeba sp.*	Nematodes
		Arcella vulgaris	Rotifers different
	Oscillatoria limosa	*Difflugia*	species
		Amoeba proteus	*Polychaeta*
		Monas	*Cyclops*
		Peranema	Larva in cyst
		Paramoecium	
		Stentor	
		Lionotopsis anser	
		Oxytrichida	
		Vorticella	
		Pyxidium	
		Scyphidia fromentellii	
July 5	*Oscillatoria limosa*	*Arcella* shells	Rotifer
	Microthamnion kützingianum	*Chaenia*	Nauplius of Cyclops
		Stentor	Ecdysis of Cyclops
		Vorticella	*Polychaetus*

TABLE V (*Continued*)

Date	Bacteria and Algae	Protozoa	Metazoa
July 6		*Euglena* *Plagiopyla* *Metopus sigmoides* *Loxophyllum*	
July 13	*Sphaerotilus natans* *Zoogloea ramingera*	*Amoeba proteus* *Arcella vulgaris* *Arcella discoides* *Peranema trichophorum* *Chilodon* *Paramoecium* *Lionotopsis* *Amphileptus meleagris* *Colpoda* *Vorticella* *Vorticella elongata* *Opercularia berberina*	*Rotifera* *Doro limosa* Nauplius of Cyclops Male and female of Cyclops *Torrenticula anomala*
July 14	*Richteriella* An attached cyst	*Amoeba limax* *Arcella vulgaris* *Arcella dentata* *Vahlkampfia minuta* *Colpidium* *Colpoda*	*Dorylainus* Nauplius of Cyclops
July 16	*Zoogloea ramingera*	*Arcella vulgaris*	Nematodes *Philodina roseola* *Doro limosa*
August 3	*Zoogloea ramingera*	*Arcella vulgaris* *Difflugia* *Vorticella*	Nematodes *Philodina roseola* *Pristina longisata*

Life in the River at the Plant Outlet.—No study was made of the life in the secondary settling tanks since it should be similar to that of the sprinkling filter effluent. A single sample of the mixed effluent and river water taken near the outlet of the sewage plant contained the following organisms:

Algae	Protozoa	Metazoa
Asterionella gracillima	*Astasia*	A rotifer
A green cyst	*Euglena minuta*	A nematode
	Peranema trichophorum	
	Euglena sp.	
	Trachelomonas	
	Coleps hirtus	

A larger number of samples and a more thorough search would have shown a larger variety of species. A sample from a mud bank near the outlet from the plant revealed the following:

Algae	Protozoa	Metazoa
Diatoms	*Amoeba limax*	*Diglena rostrata*
Oscillatoria	*Amoeba proteus*	*Rotifer neptinius*
	Euglenoids	*Lepidoderma*
	Peranema	*Anguillula*
	Synura	
	Paramoecium caudatum	
	Several small ciliates	
	Loxocephalus granulosus	
	Stentor	
	Uroleptus longicaudata	
	Oxytricha pellionella	
	Aspidisca costata	

This summary shows that the flora and fauna of the river near the outlet resemble the flora and fauna of the sprinkling filter effluent. Many of these organisms serve as food for the large numbers of aquatic beetles, (Dytiscids, Hydrophilids and Gyrnids) which frequent the surface of the river near the outlet.

Schools of fish are fond of the final effluent as it enters the river with its large supply of fish food. The following fish have been caught at the plant outlet; catfish, carp, buffalo fish, golden shiner, crappie, bluegill, gizzard-shad, sunfish, chubs and minnows.

Conclusions

1. The crude sewage of Decatur contains fewer organisms than other investigators have reported. This is probably due to inhibitory substances in the industrial wastes.

2. The flora and fauna of the digestion compartments of the Imhoff tanks are quite similar to the flora and fauna reported by Lackey (1925) for non-foaming tanks, except for *Zoogloea* and *Sphaerotilus*.

3. The sludge in the pre-aeration system consists almost entirely of *Zoogloea* and *Sphaerotilus*.

4. Increased aeration favors the succession of small flagellates, hypotrichous and then peritrichous ciliates.

5. This sludge, although relatively free from protozoa and classified as a poor activated sludge, causes a reduction of about 30 per cent of the total B. O. D. in the crude sewage.

6. The presence of about 8 p. p. m. of dextrose in the sewage probably encourages the abundant growth of *Sphaerotilus* in the aeration tanks and may also account for its presence in the Imhoff tanks.

7. The flora and fauna of the sprinkling filter effluent contain mostly protozoa of the mesosaprobic purification zone, and is similar to that of other filters reported in the literature.

8. Ten species of fish have been caught in the river at the plant outlet feeding on the life in the filter effluent.

9. The final effluent from the plant during these studies was better than 90 per cent stable and contained about 11 p. p. m. nitrates.

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Comparison of Diffused-Air and Stream-Flow Aeration in Purification of Packing House Wastes[1]

BY MAX LEVINE, HARRY N. JENKS AND F. G. NELSON[2]

In the spring of 1927, the Jacob E. Decker and Sons Packing Company of Mason City, Iowa, made a grant to the Iowa Engineering Experiment Station to study and develop methods for the purification of packing house wastes, with special reference to their local situation. An activated sludge plant had been installed in 1921, and enlarged in 1923, but the degree of purification effected was low and the cost of operation extremely high. It had been intimated to the Decker Company that the high salt content of their waste (frequently 2500 p. p. m.) might be responsible for the poor results with the activated-sludge process, and we thought that mechanical aeration might markedly reduce the cost of operation. Experiments were therefore planned to ascertain the suitability of the activated-sludge process for treatment of the peak-flow wastes of this plant and to develop a satisfactory means of mechanical aeration. The method of mechanical aeration devised has been described in a paper by Jenks and Levine,[3] as "stream-flow aeration." It is the purpose of this paper to submit a summary of experimental results obtained by "diffused-air" and "stream-flow ' aeration of packing house wastes.

Diffused-Air Tank.—There was available at the plant a wooden tank, 3.5 feet square and 14 feet deep, which was fitted, on the bottom, with a filtros plate one foot square. This was employed for the diffused-air observations. Aeration through this filtros plate was abandoned after about two weeks because of clogging difficulties, probably due to intermittent operation on the fill-and-draw basis. An iron pipe with $^1/_8$-inch perforations, placed on the bottom of the tank, was found to give excellent aeration.

This unit was operated on the fill-and-draw basis for the period July 12 to August 27, 1927, in the following manner. It was filled with settled sewage, during the peak flow and concentration, to a depth of 12 feet and aerated for 22 hours, after which the contents were allowed to settle for one hour, the supernatant 80 per cent of liquid withdrawn, the tank refilled with peak flow waste, and the process repeated. Aeration was continued an additional 24 hours over Sundays. Aeration was at the rate of 0.65 cubic foot per gallon per hour.

Stream-Flow Tank.—The stream-flow aeration unit consisted of a

[1] *Read at the Am. Pub. Health Assocn. Convention, Sanitary Engineering and Laboratory Sections, October, 1928.*

[2] *Engineering Experiment Station, Iowa State College, Ames, Iowa.*

[3] "A Stream-Flow Sewage-Treatment Process," *Eng. News-Record*, **100**, 21, 808–813 (May, 1928).

small tank about 16 inches in diameter, 18 inches high, with a trough 6 feet long and 6 inches wide. The waste was pumped from the bottom of the tank onto the trough, which had a fall of about 4 inches in the 6-foot flow, back into the tank. The trough was provided with cleats about $^1/_4$ inch thick which caused riffles as the waste flowed over them, thus giving the appearance of a turbulent stream. The capacity of the tank was 15 gallons. The small gear pump employed circulated about 15 gallons per minute at the beginning but lost at least 20 per cent capacity during the course of the experiments.

The waste employed was the same as that used for the diffused-air tank. Operations were begun July 12, 1927, by adding 15 gallons of sewage. The pump was started and pumping continued for 22 hours, after which the mixture was allowed to settle one hour, the supernatant 80 per cent of liquid withdrawn and replaced with peak flow waste, and the process repeated. Aeration was continued an additional 24 hours over Sundays.

Sampling.—Both tanks were put into operation on July 12 and operated until July 18 to develop an activated sludge before sampling was begun. Thereafter, daily samples for bi-weekly composites were taken (until the end of the experiment, August 27) and preserved, as follows:

a. Two hundred cc. of the raw waste was taken at each period of filling, put into a large bottle containing chloroform, and immediately placed on ice.

b. After 6, 12, 18, and 22 hours of aeration (or circulation), 500-cc. samples were withdrawn in Mason jars, allowed to settle $^1/_2$ to 1 hour, and 200 cc. of the supernatant liquids taken for the corresponding composites and preserved with chloroform on ice as described for the raw wastes.

Samples for the determination of biochemical oxygen demand were taken two or three times a week, at the same time and in the same manner as described for the bi-weekly composites, but immediately examined.

Results

The results for the three series of analyses of bi-weekly composites of daily samples and the determinations of biochemical oxygen demand are summarized in Table I and Figure 1.

The method of conducting these experiments was such as to insure a well aerated sludge (because of the long aeration period employed) whenever a new charge of sewage was added. Sludge was quickly developed, both the stream-flow and diffused-air units showing over 10 per cent by volume in one hour's settling after six days of operation. At no time was there any evidence of abnormal color of sludge in the stream

flow unit, but on several occasions the liquor in the diffused-air tank developed a greenish tinge during the first four to six hours of aeration. Bulking was observed with both sludges.

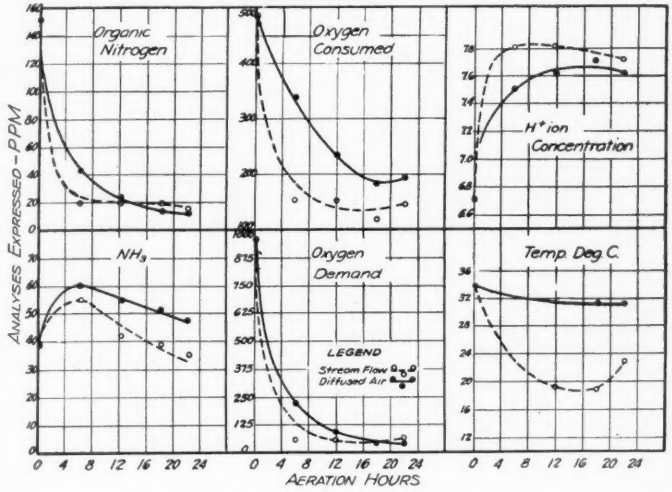

FIG. 1

In general, aeration for periods beyond 12 hours produced relatively little additional improvement in the character of the supernatant liquid, but the prolonged aeration was undoubtedly of service in re-conditioning the sludge.

Discussion of Chemical Results

Solids.—The high content of chlorides in the waste (2250 p. p. m. as NaCl) made it difficult to determine accurately volatile solids; this determination was therefore given up as unreliable for the waste in question.

Suspended solids fluctuated considerably. In general, from 50 to 85% of the suspended solids were removed in 6 and 12 hours treatment, respectively, by both methods of aeration, but it was noted that, aside from the 6-hour samples, the diffused-air effluents (12, 18 and 22 hours) were more sparkling than those from the stream-flow plant, which had a brown tinge.

Organic Nitrogen.—Removal of organic nitrogen was distinctly more rapid by stream-flow aeration. This was true not only for the average result but for each of the three series of composites observed.

Ammonia Nitrogen.—Aeration for 6 hours caused a marked increase

TABLE I

PURIFICATION EFFECTED BY DIFFUSED-AIR AND STREAM-FLOW AERATION OF PACKING HOUSE WASTES (JULY 18 TO AUGUST 27, 1927)

Aeration hours	0	6	12	18	22
Process			Total Solids		
Diffused air	4268	3373	3257	3279	3221
		(20.9)	(23.7)	(21.3)	(24.5)
Stream flow	4268	3573	3335	3173	3219
		(16.2)	(21.8)	(25.7)	(24.6)
		Solids (Exclusive of Chlorides Calculated as NaCl)			
Diffused air	2016	1121	1005	1027	969
		(44.4)	(50.1)	(49.1)	(51.4)
Stream flow	2016	1321	1083	921	967
		(34.5)	(46.3)	(54.3)	(51.4)
		Suspended Solids			
Diffused air	523	225	89	263	37
		(56.9)	(83.0)	(50.0)	(93.0)
Stream flow	523	500	74	10	82
		(4.6)	(85.8)	(98.1)	(84.3)
		Organic Nitrogen			
Diffused air	151	42	23	13	12
		(72.2)	(84.8)	(91.4)	(92.0)
Stream flow	151	19	19	18	14
		(87.4)	(87.4)	(88.0)	(90.8)
		Ammonia Nitrogen			
Diffused air	39	60	55	51	47
Stream flow	39	55	42	39	35
		Oxygen Consumed			
Diffused air	483	338	238	182	192
		(30.0)	(50.7)	(62.4)	(60.3)
Stream flow	483	153	152	116	144
		(68.3)	(68.6)	(76.0)	(70.2)
		Biochemical Oxygen Demand (5 d. 20° C.)			
Diffused air	953	222	88	48	38
		(76.7)	(90.7)	(95.0)	(98.0)
Stream flow	953	57	51	43	58
		(94.0)	(94.6)	(95.5)	(93.9)
		Reaction (pH)			
Diffused air	6.7	7.5	7.6	7.7	7.6
Stream flow	6.7	7.8	7.8	7.7	7.7
		Temperature ° C.			
Diffused air	33.7	..	31.3	31.0	31.0
Stream flow	33.7	..	19.0	18.7	22.7

Figures indicate analyses in parts per million.
Figures in ( ) indicate per cent reduction.

in ammonia which rose from 39 to 60 p. p. m. in the diffused-air and from 39 to 55 p. p. m. in the stream-flow plant. Continued aeration was accompanied by a gradual decrease in ammonia content of both samples but the drop was much faster in samples from the stream-flow unit.

Nitrite formation was very marked by both methods of aeration and nitrates were apparently also produced, but the determination of nitrates was beset with so many difficulties because of the high chloride and nitrite contents that the results are not deemed suitable for comparative purposes.

Oxygen Consumed.—Reductions of oxygen consumed were distinctly more rapid by stream-flow than by diffused-air aeration.

Oxygen Demand.—The 5-day biochemical oxygen demand at 20° C. was determined on 16 samples during the course of these experiments. The elimination of oxygen-demanding constituents was more rapid by stream-flow than by diffused-air treatment. In general, the 5-day oxygen demand of the waste treated for 6 hours by stream flow was lower than that aerated for 12 hours by diffused air.

H-Ion Concentration.—The applied waste was generally slightly acid, pH 6.7. The reaction quickly became alkaline on aeration by both methods, rising to pH 7.5 and pH 7.8 after 6 hours diffused-air and stream-flow aeration, respectively.

Temperature.—The differences in temperature changes were particularly noticeable, as shown in the table. The temperature of the stream-flow plant was evidently affected by the outdoor air temperature, as evidenced by the rise in the 22-hour samples, but the marked drop in 12 to 18 hours was due in large part to evaporation of liquid from the aeration surface. Decreases of over 10 per cent in the volume of waste were observed in the stream-flow unit after 12 to 18 hours of circulation.

Summary

A packing house waste showing a chloride content equivalent to 2250 p. p. m. NaCl and a 5-day B. O. D. of 953 p. p. m. was subjected to oxidation (*a*) by pumping air through it in a deep tank (12 ft.) and (*b*) by affording an opportunity for oxygen of the air to be absorbed as the waste was recirculated in a thin film ($^1/_2$ to 1 inch in depth). The former method is the well-known diffused-air activated sludge process, and the latter is referred to as "stream-flow aeration."

Both methods when operated on the fill-and-draw basis were found to be capable of quickly developing a satisfactory activated sludge which could be maintained in good condition.

The diffused-air process yielded a more nearly colorless effluent and showed a somewhat better reduction in solids than the stream-flow unit, but the results as respects the elimination of organic nitrogen, oxygen

consumed and oxygen demand, were better for the stream-flow unit, as shown in the following summary table:

	Aeration Period			
	6 Hours		12 Hours	
	Diffused Air	Stream Flow	Diffused Air	Stream Flow
	Per Cent Reduction			
Total solids	20.9	16.2	23.7	21.8
Solids exclusive of chlorides	44.4	34.5	50.1	46.3
Organic nitrogen	72.2	87.4	84.8	87.4
Oxygen consumed	30.0	68.3	50.7	68.6
Oxygen demand	76.7	94.0	90.7	94.6

The wastes treated in the experimental plants were the same, and the two units were operated under as comparable conditions as possible. The difference in the sizes of the experimental units (1100 gallons for diffused air and 15 gallons for stream flow) raises some question as to whether the results are strictly comparable. The evidence is conclusive, however, that by repeatedly exposing fresh surfaces of the strong packing house waste to the air sufficient oxygen was absorbed to permit of the rapid development of a satisfactory and highly purifying activated sludge.

The authors wish to express their appreciation for the coöperation rendered by the staff of the Jacob E. Decker and Sons Packing Company, and particularly to Mr. Elmer Dye for the chemical analyses and to Professor George Burke, of the Iowa Engineering Experiment Station, for the determination of solids.

Sewage Works Operation

Difficulties with Sewage Plant Operation[1]

By John R. Downes[2]

The subject, "Difficulties with Sewage Plant Operation," provides a very wide scope for discussion. One may say without being considered unduly pessimistic that "difficulties" are the chief lot of the operator's life. If this were not true the genus "operator" as we know him today would not exist.

The very nature of the material being handled and the conditions under which the handling must be done make for difficulties. To enumerate a few of the inherent trouble makers:

(1) Sewage is essentially putrescible organic matter diluted to such an extent that we are compelled to handle approximately 5000 units (by weight) for each single unit of organic matter which we are attempting to reach.

(2) While this dilution is great in that it requires the handling of comparatively large volumes of material it must be multiplied 25 times or brought to a dilution of 1 to 125,000 in order to make it non-nuisance producing.

(3) Part of the offensive material is solid and part liquid and part in an intermediate stage which makes gravimetric separation impossible as a complete cure but absolutely essential as a partial cure or step in the process.

(4) The varied assortment of sizes of solid material ranging from the finest sand grains to anything small enough to pass through the main outfall line makes it necessary to provide channels small enough to provide scouring velocities on the one hand and large enough to prevent clogging on the other. Add to this a daily variation of flow of 1 to 5 for tight domestic sewers and 1 to 10 or more for combined sewers.

(5) Human nature and the fact that while the operator's work parallels that of the production manager, his output is worthless, and that, therefore, financing is difficult.

Enough has been said to indicate that the previous statement to the effect that "difficulties are the chief lot of the operator" is not unduly pessimistic.

[1] *Presented at First Annual Meeting of the New England Sewage Works Association, Hartford, Conn., April 23, 1929.*

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One other source of annoyance which has faced us in the past, and one to the elimination of which the writer has given his best efforts during the past fifteen years, is lack of information upon which to work.

It is to be regretted that the enormous quantity of valuable information brought out at the Lawrence Experiment Station was so largely buried in archives and left to others to develop along practical lines. It appears that there is no line of attack which we can make today but what has been followed in the past at the Lawrence Station. There was not, however, the keen appreciation of the necessity of application which the modern concentration of population is forcing upon us.

Anyone who has experienced the thrill of original investigation and the subsequent deflation of ego on trying to put the idea over on a public more interested in its more personal problems; and, conversely, anyone who has tried to follow the reasoning of an enthusiastic investigator trying to explain that which to him is perfectly clear and thrilling but which leaves the listener more or less lost and chilled, will realize how easily this really valuable but abstract information has been largely lost sight of.

The newer New Jersey Experiment Station has had the advantage of working at a time when a hundred operators are clamoring for practical solution of their problems. The laboratory and the plant are working side by side. Sometimes the laboratory tells the operator what to do and as often it is simply called upon to check up and explain what has already happened.

The findings thus immediately appropriated for practical use will make an indelible impression on the public. Inevitably, there will be volumes of abstract information not fixed in the public attention by practical application, which will be buried and forgotten.

Now to get down to concrete illustrations of difficulties and how they are met. Perhaps it would be well to go step by step through a plant which has been developed piecemeal to meet the difficulties which have from time to time been encountered.

Grit Chambers

In the particular plant under discussion the grit chamber was not a part of the original layout since the plant was designed for strictly domestic sewage. Subsidence of sewer lines laid in quicksand with consequent opening of joints, and the passage of the eighteenth amendment are two factors which have combined to introduce into the sewers a quantity of sand and mash which, getting into the settling tanks, seriously interferes with the removal of sludge. This is because the heavy material separates quickly from that which is lighter and settles in a compact, impenetrable mass about the base of the sludge removal pipes.

Considering what has already been referred to, the daily variation in flow

with a maximum rate 5 times the minimum, it seemed hopeless to attempt to develop by any formula, a design of grit chamber which would cause the uniform deposition of sand and the passing on of organic solids. Extended observations of the behavior of solids in entrance channels where velocities are progressively decreased have indicated that a large proportion of the coarse solids are settled in one minute at a velocity of one foot a second. If, then, a chamber be so proportioned as to meet these conditions at the maximum daily rate of flow we shall retain all the heavy, mineral solids and considerable of the lighter organic solid material.

We are glad enough to get this coarse organic material out of our settling tanks and out of our digestion tanks. The fetish for grit chamber designs which precisely differentiate between organic and non-organic solids arises, be it remembered, not from any desire to have the organic matter in the settling tank, but to exclude it from the inorganic grit which is often used for fill.

Experience teaches us that the exclusion of these coarse, organic solids from the settling tanks is often distinctly advantageous, in that it minimizes the production of sludge blankets, the sticking of valves, the stoppage of pipes and the interference with sludge pumping operations. We have learned also, that floating solids scattered over the surface of the settling tank are unsightly, and are odor producers. The time consumed in skimming such floating material from the rather large surface area of the tank is a sizable item of expense.

In view of the above considerations it seems wise to glorify the grit chamber a bit. Make it large enough to take the bulk of the coarse material and to provide it with a skimming weir.

Now the question arises, how to remove the solids from the glorified grit chamber and how to dispose of them. We have for a number of years used several specially designed sludge pumps which do most amazing things in the way of pumping thick sludge, sludge so thick that it remains in cakes and while a portion of the cake is being sucked up into the intake pipe the remainder climbs the outside of the pipe. These pumps have also pumped sand in such concentration that if the pump is stopped for an instant the discharge hose becomes solidly packed with sand. They have also worked successfully with suction lifts of 20 feet. It is then reasonable to suppose that they will pump the grit out of the grit chamber where the lift is three feet at the maximum.

About an hour's work with the pump on the grit chamber proves that it is entirely impractical for this work. Grape seeds and mash grains keep the valves from seating. These grains and seeds have been washed clean as they were carried along by the sewage and there is no accompanying muck, as in the case of sludge, to make a seal.

An air lift well has been found very effective in removing the solids from

the bottom of such a grit chamber. This type of lift is almost entirely free from clogging nuisances and may, if desired, discharge the grit and accompanying debris into a channel of varying cross section in which case the latter will act as a grader depositing coarse sand, fine sand, grape seed, mash and garbage at different points along its length where they may be recovered separately, if desirable, and each class of material may be disposed of independently.

Burial is the natural disposition for the organic matter in the case of small plants. The organic material may well be deposited first and covered with a layer of the clean sand. This will produce a neat surface appearance and eliminate odors. It should be pointed out here that when organic matter is disposed of by burial with a covering of six or eight inches of soil little or no nuisance results. The organic matter is digested and turned into humus and the ground can be gone over repeatedly. In some of our earlier efforts to do a really good job in the disposal of offensive organic matter by burial we buried deep, below the line of influence of humifying organisms, only to find that years afterwards when we attempted to use the ground again, the material was still highly offensive on being disturbed.

Eventually it is believed that we shall work out a satisfactory incinerator for the disposal of organic matter of this nature.

Screens

Many plants have some sort of screens preceding the settling tanks. In a few favored localities, of course, the screen is the main part of the plant. Mechanically cleaned fine screens have been developed to a point where they give very effective service with suprisingly little mechanical trouble. Whether the screen is of the mechanical type, or a hand raked bar screen, the problem of disposing of the screenings is much like that of disposing of the organic portion of the material deposited in grit chambers. Here, also, we hope that satisfactory means of incineration may be worked out: but for the present, we have the choice of burial, composting or digestion, and in a few favored localities barging out to sea.

Composting screenings as practiced at one plant here in New England is an application of the principle of shallow burial already referred to in connection with the disposal of organic matter from grit chambers.

Transfer of the screenings from the screen to the point of disposal is, perhaps, the most interesting problem of screen operation.

Where disposal is made at a definite point, air ejectors and nonclogging pumps such as the centrifugal "Woods Trash Pump" have been found very satisfactory. Either of these are available for use where disposal is made by digestion, composting, incineration or barging. Where disposal is made

by shallow burial, a common farm manure spreader is of service for distributing the screenings on the land and burial is accomplished by plowing the area on which the screenings have been spread.

A bar screen is rather a messy unpleasant thing to contend with, but the operator has the satisfaction of knowing that what he has removed at this point will not rise up to present difficulties at other parts of the plant. The theory of digesting screenings with the sludge is perfectly good from a scientific standpoint. There is no question that the screenings will digest satisfactorily, neither is there any question that certain indigestible material such as tin cans, clothes pins, etc., will eventually become lodged in sludge valves, gates and pipe bends. Reference is made to designs of plants where the coarse material is screened out to keep it from the settling tanks and then transported by means of pumps, conveyors or air ejectors directly to the sludge digestion tanks.

Observation indicates that a clean (fine) screen, which affords little loss of head, will actually remove more solids than a partially clogged screen. This statement will undoubtedly surprise many; in fact one of the later developments in screen design is one which provides for the building up of a mat of screenings, on the theory that the mat will afford smaller openings and, therefore, retain smaller particles of solid matter, than would the clean mesh. Observations over a period of ten years, however, have shown that every time a certain screen is thoroughly cleaned by forcing out lodged sand grains, etc., the volume of screenings increases by about ten per cent during the following two days.

Included in the difficulties of operation is that of sampling to determine screen efficiency. The potential errors of sampling unscreened sewage together with the mixing and disintegrating effect of the screen make direct comparison of suspended solids before and after screening a hopeless task. It has long been the practice of the writer to determine suspended solids in the screen effluent and to calculate the raw from the volume and weight of the screenings removed, and in which the moisture content has been determined.

As a matter of fact when the screen is auxiliary to sedimentation, the percentage removal by the screen has little significance, since the benefit derived from the use of the screen is out of all proportion to that indicated by a numerical expression of the percentage removal. It is only when the screen is the sole means of clarification that the percentage removal becomes important.

Maintenance of a proper seal at the junction of moving and stationary parts of a screen is equally important and difficult. An opening fractionally larger than the standard screen opening will pass solids out of all proportion to the difference in size. Any uneveness in the size of the seal opening will permit the entrance of large particles which later become

wedged in a narrowed section. The balling up of rags, a corner of which has started in at a wide point in the seal, is a particularly aggravating condition.

Sedimentation Tanks

In the design of sedimentation tanks all theories of hydraulic flow should be accepted only as subject to trial and proof.

We bring the flow through the channels and up to the sedimentation tank at a cleansing velocity and then attempt to reduce its speed to a settling velocity in a tank, the cross sectional area of which is about 20 times that of the channel. The result is the production of currents and eddies rather than anything like a uniform slow forward movement of the body of liquid which would be the ideal requirement.

Theoretically, admission of the flow through scattered restricted orifices giving a very small loss of head would give a uniform flow but the very nature of sewage prohibits the application of this principle.

The best laid plans result in unexpected eddies due to the slightest imperfections in concrete surfaces, etc., and it is only by patient trial and error that the operator can place baffles and targets to advantage so that the currents may be broken up. Baffles in the older sense of the word, fixed partitions under or over which the sewage is supposed to flow, are useless because they simply cut the tank up into a number of dead spaces, around the edge of which the sewage flows. "Targets" seems to be a better word and refers to obstacles placed in the path of obvious currents to disperse them. Particularly interesting work along this line has been done by Mr. P. N. Daniels at the Trenton, N. J., plant.

In the case of separate settling units it is usually only necessary to keep the maximum velocities in the tank down to one foot per second or less to secure good results. In the case of combined settling and digesting tanks such as Imhoff tanks, the writer indicated some years ago the desirability of maintaining rather high velocities in order to gain distribution of the solids from end to end of the tank as contrasted to the piling up of solids at the inlet end where the velocity is reduced too suddenly.

For years it has been the custom to determine and record the volume and weight of suspended solids in the raw sewage and in the sedimentation tank effluent. No one, however, seems to have made a study of what reduction is desirable under different conditions.

Mr. Glenn Holmes of Syracuse has done a large amount of work on the possible reduction in various periods of time and with various solids content in the raw sewage. He shows that a clarification of 50% in less than 5 min. is practical where the original solids are 300 p. p. m; in 22 min. where the original solids are 200; and in 55 min. where the original solids are only 100. To gain a reduction of 60% requires 22 min. with 300 p. p. m.

solids in the raw; an hour and a quarter where the solids are 200; and 3 hours where the original solids are only 100.

If, instead of percentage reduction in solids, we take as our goal reduction of solids to 100 p. p. m. in the effluent, about $1^1/_2$ hours are required for crude sewage of 300 parts of solids, about 22 mins. for crude sewage of 200 parts.

These results in Syracuse check well with results elsewhere, including our local experience, and with laboratory experiments made by Mr. Gavett in 1912 and later repeated.

So far as the operator is concerned he must know the condition of his crude sewage and the demands of his tank effluent. It would seem to be just as much a part of his duty to avoid over detention as to provide a sufficient amount thereof.

The evils of over detention are septicization of the effluent and an excess of sludge to be digested. Particularly is the latter true since it appears that finely divided organic solids may be treated more advantageously and with less potential nuisance by aerobic than by anaerobic processes.

There is room for the use of good judgment in determining the capacity of such aerating devices as follow sedimentation tanks.

Aerating Devices

Following sedimentation the liquid portion of the sewage is ordinarily treated by either sand beds, contact beds, sprinkling filters or possibly activated sludge.

In the case of sand filters, mechanically speaking, the highest efficiency in sedimentation should be our aim. The same is practically true in the case of contact beds, the periodical cleaning of which to remove collected solids is a major item of expense. There is still much difference of opinion about the effect of suspended solids on the activated sludge process and, therefore, on the extent to which it is advisable to push sedimentation if this process is used ahead of activated sludge.

Sprinkling filters are devices which will stand considerable abuse and which have an enormous recuperative power. The writer believes that it is a perfectly legitimate part of his duty to use discretion in distributing the lighter solids between the digestion tanks and the sprinkling filters; in other words, that it is not necessarily always wise to try to get the highest efficiency out of sedimentation tanks when they are followed by sprinkling filters. Some of the lighter and more finely divided solids which settle with difficulty produce unpleasant conditions in digestion tanks, particularly in the digestion compartments of Imhoff tanks. They contribute largely toward foaming and the production of odors. The same solids may be handled without production of odor and without undue clogging effect under the aerobic conditions in a sprinkling filter.

Further, the forcing of sedimentation by long detention periods tends to stale the sewage and thus produce odors at the sprinklers. The typical curve for quiescent settling of sewage solids flattens out in from 20 to 30 minutes, for practical tank settling conditions in one hour. Generally speaking a tank designed on the basis of one and one-half hours detention (displacement) period will yield about 45 minutes actual detention and it is a question whether a long period should be sought for.

It has been said above, that "mechanically speaking" the highest efficiency in sedimentation should be sought when sand filters or contact beds are to follow. It is a question, however, whether the mechanical clogging of such units by the finer solids will be more serious than the deoxygenating effect of the long period of time required to remove such solids by sedimentation. It should be remembered that a small amount of septic material has a very bad clogging effect as compared with a much larger quantity of healthy fully oxygenated solids.

The discussion thus far indicates that we can not consider any one unit of a disposal plant independently of the other units which make up the whole. Turning now from consideration of the effluent of the sedimentation tanks to the consideration of the deposited solids we find the same thing emphasized.

Sludge Digestion

Interrelated with the subject of sludge digestion are not only the matter of efficiency of sedimentation above referred to, but also the effectiveness of provision for removing the deposited solids from the sedimentation tank to the digestion tank and the adequacy of provision for final disposition of the digested sludge.

From the tables in *Bull. 132*, U. S. Public Health Service, "Sewage Treatment in the United States," Wagenhals, *et al.*, we find that in various cities reported upon, the weight of solids retained by settling tanks varies from 39 p. p. m. to 168 p. p. m. Considering only the domestic sewage the variation is from 52 to 168.

With such variation in the quantity of solids removed by various plants we surmise that the "high efficiency" of the digestion units of some plants as reported may, in fact, be merely the low efficiency of the sedimentation tanks; while the difficulties encountered in the digestion of some sludges may be due to the fact that the sedimentation units are actually working at high efficiency and thus retaining not only a large quantity of solids, but the finest and most troublesome class of solids which by their very nature have escaped the inefficient settling tank.

With regard to the effectiveness of removal of the solids from the settling tank to the digestion tank, it may be said that hours of delay in getting these solids into contact with old ripe sludge may be reckoned as days so far as

the retardation of the digestion process is concerned. This is because the rapid production of organic acids in the first stages of digestion produces inhibiting effects which bring the entire process to a temporary halt unless the acid is neutralized by either mixing the green solids with old alkali-producing sludge, or mixing neutralizing chemicals, such as lime to the green solids.

FIG. 1

The relation to sludge digestion of adequate provision for final sludge disposal is obvious when we stop to think that sludge continues to occupy valuable space until removed from the digestion tank and we are nothing ahead by using modern methods to accelerate digestion unless we provide for removing the finished product. The situation is analogous to a factory working on a full production schedule but with no sales outlet.

An excess of digestion capacity is an excellent fault in any disposal plant, but lacking such excess the operator must follow the strictest routine of additions and withdrawals of sludge in order to keep the process in balance. If facilities for prompt removal of the old ripe sludge are lacking, it will be impossible to adhere to this routine and, therefore, impossible to keep the green sludge moving into contact with the old neutralizing sludge.

In such a contingency it is necessary to turn to chemicals such as lime for a neutralizing agent.

In the case of two-story (Imhoff) tanks lack of digestion space results in lodging of the fresh solids at the slot in segregated masses and we again have the production of organic acids with their inhibiting effect. Faulty slot construction may also result in a similar situation and in either case it may be necessary to use lime.

The accompanying illustrations show the method of treating Imhoff tank sludge with lime to adjust reaction. Sludge is pumped from the bottom of the tank to the trough shown resting on the tank walls and allowed to fall back into the gas vent. As the sludge passes through the trough, lime is added by means of the homemade lime feed apparatus. In Figure 1 lime may be seen falling on the surface of the sludge. The fall of the sludge to the surface of the liquid in the gas vent accomplishes the necessary mixing. On a sill supporting the lime feed are three beakers containing (from left to right) undertreated sludge, untreated sludge and properly treated sludge. Note the clear separation of liquid in the latter. Figure 2 shows the same apparatus, the man being introduced to indicate the size of the parts.

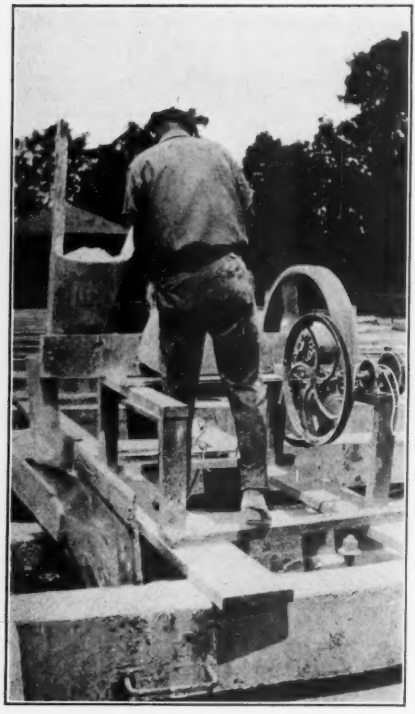

FIG. 2

Odors

Odors are another major source of difficulty for the operator.

Odors naturally divide themselves into two classes; local, and migrating. Local odors are such as may emanate from exposed sewage solids about screens or where they may have been carelessly dropped by attendants or grease cakes forming just above the flow line of tanks and cooking in a hot sun. Such odors and those about small pump stations are very annoying close at hand but would not be noticeable, say, 50 yards from the source.

Cleanliness and the use of a good deodorant such as Phinotas will overcome the local odor difficulty though care should be taken to choose a deodorant which has an odor not worse that which we seek to overcome. By this I mean that a good, honest, ammoniacal stale urine odor is much preferable to many of the compounds used about public toilets. However, some very pleasing effects may be secured by carefully picking the proper compound.

By migrating odors I mean odors that travel more than 100 yards. This type of odor is occasionally carried by relatively high winds but is dispersed by the very wind that carries it. These odors become really troublesome under the peculiar atmospheric conditions which produce smoke flags. These conditions usually occur about dusk.

You have all noted this condition when a trail of smoke from a bonfire will hang suspended in the air a definite distance from the ground or from any object which may stand in its path. The smoke does actually travel in a definite direction but so slowly that its movement is not visible. Also, which is the crux of the situation, so slowly that it is not broken up by eddies, or dispersed, on approaching an object in its path, but flows ever so gently around such object. Usually, if you observe these smoke flags carefully, you will see that they never touch an intervening obstacle but pass around it at a definite distance. It is this phenomenon which makes shrubbery screens useless as odor controls. When there is wind velocity sufficient to cause dispersion of the odor cloud by impingement against the shrubbery well and good, but without such velocity of movement the screen is ineffective, since the analogous smoke flag is often observed to trail over an intervening forest and descend on the opposite side.

The chief offending compound in odor clouds which migrate in this fashion is hydrogen sulphide. It has been definitely shown that this gas is attacked by chlorine with the formation of substitution products resulting in odors varying from medicated (chloroform) to zero according to the quantity of chlorine used.

While the quantity of chlorine necessary for this treatment seems large when figured in parts per million, Mr. Lynn Enslow and Mr. W. J. O'Connell have developed the fact that the peak of hydrogen sulphide content is almost always coincident with the afternoon peak flow of sewage and it is only necessary to use chlorine on this peak and during the early evening hours when atmospheric conditions are ideal for formation of smoke flags.

For instance while we, at Plainfield, have to use chlorine at the rate of 400 pounds per day, we apply it for only four or five hours with a total consumption of about 70 pounds daily. Under these conditions, and with chlorine procurable at 6¢ per pound the cost for odor control during six summer months approximates $700.00.

We treat only during the summer months because hydrogen sulphide is produced in troublesome quantities only during warm weather.

Treating 25% of the settling tank effluent by the activated sludge process and mixing the activated effluent with the balance of the tank effluent very effectively destroys the hydrogen sulphide odor. From the operating point of view this is preferable to chlorine treatment, but even though we can secure our power free by making use of the gas from the digestion tanks, the carrying charges on the machinery installation for activated sludge is

greater than the cost of chlorine plus carrying charges on the chlorine feed equipment.

Whether we have simply local odors, amenable to deodorants of the Phinotas type, or migrating odors requiring chlorine or activated sludge treatment, will depend largely upon the age of the sewage, for time is a factor in the production of the troublesome hydrogen sulphide. Where the sewage reaches the plant in a fairly fresh condition, troublesome quantities of H_2S may develop in the settling tanks. It is for this reason that it was said earlier that one of the evils of overdetention in settling tanks is septicization and that it is as much the duty of the operator to avoid overdetention as to provide sufficient amount thereof.

Uncontrolled digestion of sludge with exposed surfaces is a prolific source of both local and migrating odors. However, with our present knowledge of optimum digestion conditions, there is little excuse for odors from this source. The floating covers used at the Plainfield Joint Sewage Works effectively (*a*) prevent exposure to the atmosphere, (*b*) keep all floating material submerged, in which case certain odorous compounds otherwise formed are absent, (*c*) provide a perfectly safe means of collecting the gas and making it available for heating the digesting sludge to the optimum temperature.

Sludge Handling

We have spoken of the necessity for adequate provision for ultimate disposal of the ripe sludge. It is obvious that sludge, although ripe, continues to occupy space until removed from the digestion tank. Therefore, there is no point, other than odor control, in speeding up digestion unless we provide for taking the finished product away.

Open air drying in our rigorous winter climate is obviously not adapted to the daily routine required for controlled digestion. Drying on sand beds under glass has been developed to some extent during the past three years, but the writer has no knowledge of definite data on which to judge of its success. He believes that a mechanical drying process covering comparatively small area will be the ultimate solution of this problem. Winter sludge drying seems to be the limiting factor in sewage plant operation at this time. There is no doubt that the situation can be met if we concentrate our attention upon it and it is hoped that some of the investigators in the sewage works field will turn their attention in this direction.

We have information of certain fundamental principles of the required drying process which seem to have been entirely overlooked by those who have sought to adapt industrial drying machines to this work.

For winter disposal of sludge locally, we are making use of shallow lagooning in our open fields. Light portable pipe, five-inch riveted steel is used to convey the sludge to the chosen area. The pipe line is carefully aligned to

avoid pockets and make it completely self draining to avoid freezing troubles. Diaphragm, or plunger type pumps having ball valves such as the "Mud Hog" have proven very satisfactory for forcing the sludge to distant points.

Embankments are thrown up to hold one foot depth of sludge, and sludge is pumped on the same area day after day until the banks remain full. The amount of drainage taking place under these conditions is very surprising. True we have a particularly favorable, sandy soil. Even this soil has to rest after three or four successive treatments. This method is very good pending the development of a more advanced method of winter sludge drying.

Sludge Disposal at the Calumet Sewage Treatment Works[1]

BY A. H. GOODMAN[2] AND C. E. WHEELER, JR.[3]

Description of Plant

The Calumet Sewage Treatment Works of the Sanitary District of Chicago, located at 125th Street just west of Cottage Grove Ave., is designed to treat the sewage of Chicago south of 87th Street and in addition, that of Blue Island, Riverdale, Dolton and several other small municipalities at some future period. The combined (domestic and storm water) sewage is brought by intercepting sewers to two pumping stations, one at 95th Street near the lake and the other at 125th Street and Michigan Avenue. The flow from the latter station comes to the treatment works. The design capacity of the plant is 56 m. g. d. with an allowance for a 50 per cent increase for storm flow.

The sewage is measured by a Venturi meter and then passes through a rack screen with 1-inch openings equipped with a mechanical cleaner. It flows next through grit chambers which are equipped for cleaning with a grab bucket on an electric hoist working from a gantry crane. The velocity in the grit chamber is maintained between 0.75 and 1 ft. per second. The sewage then passes to 30 Imhoff tanks each 103 ft. 6 in. long by 34 ft. 6 in. wide, and 25 ft. deep. The sedimentation compartment is divided into 3 bays. There are 3 sludge hoppers in the shape of inverted frustrums of square pyramids. Gas vent area is 17 per cent of the total surface area.

Operation of Tanks

Operation of the plant began on September 12, 1922, when sixteen Imhoff tanks were put into service. The remainder of the Imhoff tanks were started on December 16, 1922. The sewage treated is mainly domestic and somewhat weak in character. In 1924, however, paint waste began to cause trouble. Large quantities of oil are found at times. No foaming trouble has been noted from the sixteen tanks started in September but the tanks started in December went through a violent foaming period of about six weeks the summer of the next year, 1923. Since 1923 there has been no foaming in any of the tanks.

The tanks are arranged so that the direction of flow may be reversed. This is done regularly, the length of time in one direction rarely exceeding

[1] *Read at the Second Annual Meeting of the Central States Sewage Works Association, Indianapolis, Ind., June 21, 1929.*

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2 months. This program appears to give satisfactory distribution of solids throughout the length of the tanks. Routine determinations of sludge levels are taken at 3-month periods in each hopper. These levels are taken with a common pitcher pump, equipped with a suction hose, which is lowered through the supernatant liquor underlying the scum in the gas vents until sludge is encountered. This method has proved to be the most dependable of any tried.

Disposal of Imhoff Sludge

Sludge is removed from the sludge hoppers by an air lift. Water rings of perforated brass pipe are installed in each sludge hopper to stir up heavy sludge and to aid its movement, also to allow of some mixing of the digesting sludge mass. After being pumped from the hoppers the sludge runs by gravity to the original drying beds, which are adjacent to the tanks, or to 2–150 gal. per minute Jennings pneumatic ejectors, which force the sludge to the additional beds installed in 1927. The total sand bed area at the present time is equal to 0.67 sq. ft. per capita on the designed population of 225,000 people or about 1.0 sq. ft. per capita on the present population. Sludge as wasted varies in moisture from a yearly minimum of 87.2 per cent water to a yearly maximum of 89.1 per cent. Average moisture of sludge over five years of operation has been 87.8 per cent.

Sludge is usually placed on the beds to an average depth of 9 to 11 inches. At certain times of the year, in order to use the drying area to greater advantage, the depth is increased to 15 to 16 inches. Filling 9 to 11 inches in average good drying weather permits the sludge to be removed from the beds in about two weeks, with a yearly average moisture content varying from 39.3 to 55.1 per cent. Sludge has been removed by hand with forks and carried away by a system of narrow gage railroad tracks and dump cars. The original sand beds are 66 ft. long and vary in width from 17 to 20 ft. The 24 in. gage industrial track is installed lengthwise in the center of each drying bed with a complete system of switches and main track for assembling trains outside. The new beds are 105 ft. long and 65 ft. wide with a similar track system going into the beds, 5 rows of track to each bed, making the distance between center line of tracks 22 ft. Motive equipment consists of three Plymouth industrial gasoline locomotives and forty $^3/_4$-yard dump cars.

The sludge is removed from the beds by hand forking into the cars, the cars are assembled and hauled to a sludge dump for disposal at the north end of the property. This dump was built up on the clay spoil from the plant construction and is about 700 ft. long. The track is laid the long way of the dump. As the sludge accumulates it is pushed over the edge of the bank by a Parson's backfiller. This has facilitated greatly

the handling of sludge at the spoil bank, and with the improved distribution the track must be moved not more than once per year.

Some figures on sludge quantities and analyses may be of interest.

IMHOFF SLUDGE REMOVAL DATA

Year	Wet Sludge Pumped from Tanks Total Cubic Yards	Moisture, %	Dry Sludge Removed from Beds Total Cubic Yards	Moisture, %
1923	7557	87.2	3289	44.1
1924	13039	87.3	3938	41.2
1925	16073	89.1	7080	46.7
1926	18323	87.3	7524	51.3
1927	19864	87.5	7990	39.3
1928*	13999	88.1	6014	55.1
Total	88855	526.5	35835	277.7
Av.		87.8		46.3

* Plant shut down 4 months.

Total dry solids removed for six years—34,243,630 lbs.

Dry sludge weight per cubic yard as removed 1500 lbs.

SLUDGE ANALYSIS

Sample and Year	Moisture, %	Nitrogen, %	Volatile, %	Fixed, %
Sludge from beds—'24	53.3	1.68	41.6	58.4
Sludge dump top—'23	43.3	1.33	32.8	67.2
Sludge dump intr.—'23	...	0.98	27.9	72.1
Sludge from beds—'27	52.45	2.00	40.2	59.8
Sludge dump top—'26	30.22	1.48	38.7	61.3
Sludge dump intr.—'26	46.86	0.99	42.6	57.4

Open and Glass-covered Drying Beds

Experimental work has been carried on at this plant to compare drying on open beds and drying on glass-covered beds. The glass enclosures are of standard green-house construction built over two of the 17 ft. 7 in. by 66 ft. 4 in. drying beds. Two adjacent open beds of the same size are used for controls. With only the natural ventilation that could be obtained by the side and top ventilators, tests indicated that there was practically no improvement over the rate of drying on open beds. After this had been demonstrated a Buffalo Forge Co. fan was installed for forced ventilation to replace the moisture-laden air above the sludge with air from the outside. In extreme winter conditions the air is heated in an attempt to keep the sludge from freezing but it has been impossible to keep the temperatures in the green-house enclosure above freezing at all times with the facilities available. During a year's operation with circulation of air and heating in the cold months 8 dosings and removals were made on the open beds while 12 were obtained on the covered beds. The open and covered beds were operated under parallel conditions with regard to quality of sludge, depths on the beds and moisture content at removal. Dried sludge was removed from the covered beds and controls as soon as practicable. Average daily temperatures inside the covered beds

in the winter period did not go below freezing although there were several occasions when the minimum daily temperature was below freezing. More work is to be done along this line the present year.

Record of Temperatures, Imhoff Tanks

A record has been kept at this plant since May, 1924, of the temperatures in the sedimentation chamber and sludge compartment of an Imhoff tank. The lowest average monthly temperature in the sludge compartment over the period of our record has been 40° F., which has also been the lowest temperature for the flowing-through compartment. The maximum for the sludge compartment occurred in September, 1926, and was 70° F., while the maximum for the incoming sewage on several occasions during August and September has been 69° F.

For the three years over which we have complete records the following condition prevailed.

No. of Months	1925	1926	1927
Below 50° F.	5	4	2
Above 50° F.	7	8	10
Above 60° F.	4	6	4

These figures indicate that in Chicago and vicinity for an average of 4 months per year temperatures in unheated digestion tanks will be so low as to retard digestion processes very noticeably.

Digestion of Settled and Activated Sludge

Digestion of primary sludge and excess activated sludge has been studied on a large scale. These tests extended over a period of three years. An average of 1.75 m. g. d. of sewage was settled in an Imhoff tank and the effluent was treated by the activated sludge process. The waste activated sludge was returned to the incoming sewage of the Imhoff tank.

After six months of operation it was apparent that additional sludge digestion capacity was needed to provide storage for the bulkier sludge from the activated sludge process. An additional Imhoff tank was used to supply the extra capacity required. This was operated as a separate digestion tank. The partially digested sludge was pumped over into this second Imhoff tank where the digestion was allowed to continue until the sludge was in satisfactory condition for drying.

The activated sludge was wasted as slowly and as gradually as possible in order to obtain as nearly as possible continuous mixing of activated with fresh sewage solids in the Imhoff tank. Occasionally the flow of activated sludge had to be shut off so as not to withdraw too much from the activated sludge process. The combined sludge after digestion had all of the characteristics of Imhoff sludge produced at the plant except that it averaged about 2 per cent higher in moisture content as drawn, contained

somewhat higher total nitrogen, and cracked into much smaller sections in drying.

Average figures for the entire period of experiment gave the following results: 9.4 cu. yds. per m. g. of activated sludge at 98.5 per cent moisture mixed with 2.2 cu. yds. per m. g. of fresh sewage solids at 90 per cent moisture (est.) gave 2.4 cu. yds. per m. g. of combined sludge at 89.8 per cent moisture. This amounts to an 80 per cent reduction in volume. The digestion of dry solids was based on determinations of suspended solids in the influent and effluent of the Imhoff tank and on the actual quantity of activated sludge wasted. These data over a long period indicated 32.5 per cent digestion of suspended solids.

This experiment at the Calumet Sewage Treatment Works indicated the practicability of satisfactory digestion of Imhoff and activated sludges. This procedure was adopted in the design of the West Side Treatment Works, where the waste activated sludge of the North Side Treatment Works will be mixed with the fresh incoming sewage of the West Side plant and the mixed settled solids digested.

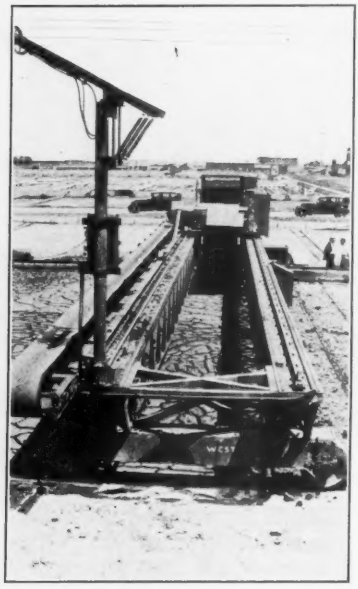

FIG. 1.—West view of sludge-removal machine.

Mechanical Removal of Sludge

Mechanical sludge removal from drying beds became important to the Sanitary District with the development of the West Side project. Experimental work has been carried on at the Calumet plant for the last 3 years to help in the solution of this problem. Small-scale work was started with a roughly built cleaner which worked on a narrow gage platform car. This consisted of a set of fingers bolted to a sheet metal tray equipped with an angle-flight elevating mechanism for moving the sludge up the pan to the dumping position. The machine was pulled through the bed by a car-puller. The width of the strip taken was approximately 4 ft. This machine demonstrated the feasibility of the plan and the fact that sludge could be taken off a drying bed mechanically without removing excessive quantities of sand with the sludge.

The next development was a machine of quite similar principle with a span of approximately 16 feet. Different shapes of elevating angles were used. A ribbon conveyor was suggested by the Link Belt Company for the sludge away from and across the teeth to concentration points where it could then be elevated. This machine further indicated the practicability of the scheme.

In the fall of 1928 a practical working machine was constructed to operate over six of the new sludge drying beds (105 ft. × 65 ft.). This machine is a double truss structure spanning the width of the beds and supported by rails on side walls. The narrow gage track system was removed from the drying beds. The machine traverses the total length of the six beds. The equipment is completely motorized, receiving its power from a trolley system extending lengthwise of the beds.

FIG. 2.—North view of sludge-removal machine.

The machine was developed by the Evers-Sauvage Engineering Company (Figures 1 and 2). It consists of a series of specially shaped buckets working on an endless vertical chain quite similar to a ditch digging machine. The buckets are equipped on their cutting side with sharpened teeth and cut a strip of sludge about 4 ft. wide across the narrow dimension of the beds. The carriage carrying the buckets moves into the sludge by a drive which is independent from that which runs the bucket elevator. The buckets dig into the sludge at a speed of 20 ft. per minute. The speed of the elevator is sufficient to raise the sludge as rapidly as it is forced into the buckets. The buckets dump into a short cross belt conveyor which in turn discharges onto a large belt which travels across the width of the bed and discharges into the narrow gage dump cars. These cars

are pulled along by a gasoline locomotive as the sludge machine moves forward on the bed.

In some preliminary tests that have been made on the machine this summer the capacity on sludge of about 55% moisture and from 5 to 6 in. deep appears to be about 1.25 cu. yd. per minute. The buckets can be elevated or lowered to strike the exact sand level. They appear to pick up an almost negligible quantity of sand. There are several ways in which the capacity of this machine may be increased.

Collection of Gas from Imhoff Tanks

Closely connected with the problem of sludge disposal is the collection of gas from digesting sludge. One Imhoff tank was equipped with gas collectors in the gas vents, the total number of separate vents covered being 24. Half of these were equipped with collectors of the Imhoff type consisting of a submerged collector sloping upward from ends to center where a small opening is provided, covered with a screen of loosely laid tongue-and-groove material. This screen is to hold back scum and permit the passage of gas into the small collecting can. The Sanitary District type consists of a longitudinal sheet metal collector, which covers the whole gas vent area. There is a water seal around the edges and simple deflectors beneath, to direct the rising gas into the collector. On this type no screen of any sort is provided to check the rising of the scum.

The formation of scum under both types of collectors has been the principal operating difficulty in collecting the gas. The screens on the Imhoff type plugged very shortly after this tank was put into operation. They were then removed.

Gas production varies greatly in unheated tanks due to the wide variation in temperature. In this climate the month of maximum production is usually September and the minimum February. The quantity of gas produced in September may be from 5 to 10 times as great as the production in February. The average production for the year 1927 was 0.406 cu. ft. per capita per day and 5.15 cu. ft. gas per lb. of volatile matter. The analysis of the gas for a period of one year gives the following figures:

Carbon Dioxide		Oxygen		Methane		Nitrogen		B.T.U./Cu. Ft.	
Max., %	Min., %	Max., %	Min., %	Max., %	Min., %	Max., %	Min., %	Max.	Min.
26.5	8.2	0.8	0.1	84.1	64.0	18.3	2.0	848.6	650.8

A typical complete analysis being:

14.2	0.3	74.4	11.1	750.7

This includes a brief summary of some of the varied phases of routine operation and experimental work connected with sludge disposal at the Calumet Treatment Works.

Cost Data at the Baltimore Sewage Works

BY C. E. KEEFER[1]

The keeping of accurate and detailed cost data of the maintenance and operation of sewage works is a matter of prime importance for many reasons. These records are of special value to the plant superintendent, as they enable him to compare one year's costs with another. Furthermore, where plans are being considered to replace a portion or all of the plant with other treatment units, a more logical decision can be reached if accurate operating costs are available for study and comparison. These costs serve a wider field if they are published, and thus become available to sewage works superintendents and engineers. In view of these facts it has been the policy for a number of years at the Baltimore sewage works to prepare detailed cost figures. Although the methods followed in keeping these records are essentially the same as for other municipal or private undertaking, the general principles involved will be briefly presented. Tables of segregated costs are given covering the operation of the Baltimore plant.

Generally speaking, there are two items which, when added together, give the total cost of sewage treatment. The first of these is the fixed charges, which include the interest on the original investment and the depreciation of the improvement. The second item, with which the sewage works operator is particularly concerned, covers operating and maintenance costs.

Interest and Depreciation Charges

The first cost of a plant is usually known at the time it is put into operation. This cost should include not only the money paid contractors for construction expenses but also such items as the cost of the property on which the plant is built, engineering and architects fees, administrative and overhead expense, discount on the sale of stock, and other preliminary expenses. In case it is impossible to obtain some or all of these expenditures the sewage works operator should prepare an estimate of the total cost of the plant. With this cost established, together with the rate of interest and the par value of the stock, which is sold to finance the project, it is possible to calculate the annual interest charge.

From time to time improvements—perhaps of a minor nature—will be made. The cost of these should be added to the first cost of the plant even though the funds allotted for the work were originally intended for operation and maintenance purposes.

To determine the annual depreciation charge it is necessary to assume some future date when the sewage plant will have to be rebuilt because

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of obsolescence or because of its deteriorated condition. The progress that has been made during the last five or ten years in sewage treatment would indicate that many sewage works will have to be rebuilt because of obsolescence rather than because their useful life has terminated. For this reason it becomes difficult to estimate depreciation charges. As indicated in Table I the useful life of the Baltimore sewage works has been assumed to be $33^1/_3$ years. A considerable portion of the plant has now been in service for 17 years, and it is believed that a large part of it would give service for another 30 or 40 years. It is likely, however, that future advances in the science of sewage treatment will not justify continuance of the present method of treatment at Baltimore for that length of time. In fact, plans embracing extensive changes are now being prepared.

With the useful life decided upon the next procedure consists of selecting the most desirable method to follow in calculating the depreciation. Several ways of determining this charge are available, such as the straight-line method, the diminishing-value plan and the sinking-fund plan. These three methods will not be discussed other than to say that each possesses certain advantages. It would seem most desirable to use the sinking-fund method for determining the depreciation of public improvements. This plan consists of setting aside each year a sum of money so that at the end of a predetermined time—the estimated life of the improvement—the sum total, including the accrued compound interest, will equal the first cost of the project less its scrap value. The annual installment, "I" (depreciation charge) necessary to set aside for a term of "n" years at an interest rate of "i" to provide a sinking fund "S" can be expressed by the formula

$$I = \frac{Si}{(1+i)^n - 1}$$

After the fixed charges have been calculated, it then becomes necessary to determine the annual running expenses of the plant.

Operation and Maintenance Charges

The sewage works superintendent desires to know not only the total cost of operating his works but also the cost of running the various treatment units of the plant. This information can be obtained by assigning charge numbers to each phase of the operation, such as screening, grit removal, sedimentation, oxidation, sludge digestion, sludge drying, and maintenance of grounds. All money expended, both for labor and materials, can then be properly segregated. In order that the segregations may be intelligently made at those plants where electric power units are used, wattmeters should be provided to register the power consumption at the various parts of the plant.

It is frequently desirable to keep operation and maintenance costs

separate, with each of these items further segregated into labor and materials. Operation charges should include such items as labor required to clean sewage screens, to attend to the operation of settling tanks, to remove sludge from drying beds, electric-power used to operate sewage and sludge pumps, chlorine used for treatment purposes, chemicals and supplies. Maintenance charges are embraced in such items as labor and materials needed for repairs, the painting of buildings and the storage of materials and supplies.

It is of particular importance that daily records of the quantity of sewage treated be obtained, together with the approximate number of persons served, so that the cost per million gallons of sewage and the cost per capita per year can be calculated. The general character and strength of the raw sewage should be known, as the cost of treatment is dependent thereupon.

It often becomes difficult to decide whether the cost of certain work should be added to the first cost of the plant, or should be included in the maintenance charges. The circumstances surrounding each case must be known before a satisfactory decision can be made. Let it be assumed, for example, that a pump is purchased for handling sludge. If the plant had never been equipped with such a unit, the installation should be classed as a new improvement, and the cost incorporated in the first cost of the plant; if the pump replaces another unit of the same kind because the latter has worn out, the first cost of the plant remains the same and the cost can be charged to depreciation reserve, but if the above replacement were due to the existing pump being damaged, the cost should be added to the maintenance of the plant.

Cost of Operating the Baltimore Sewage Works

The cost of operating the Baltimore sewage works from 1921 to 1928 is shown in Tables I and II. Table I gives both the fixed and the operating costs on a million gallon and a per capita basis. It is of interest to note that during this period the fixed costs have fluctuated over a narrow range from a minimum of $0.337 to a maximum of $0.371 per capita per year, a variation of about 10 per cent. The per capita operating costs have fluctuated more widely, from $0.143 to $0.191. The operating costs per capita reached a maximum in 1922, and since then they have been decreasing, due chiefly to a greater number of persons being served.

In Table II the costs have been segregated under ten different headings. These costs, as well as those given in Table I, do not contain any salaries other than paid to the employees at the sewage works. Thus, general overhead is not included. The cost of superintendence, including the salaries of chemists, clerks, foremen, watchmen, and janitors is distributed over the ten items in Table II.

TABLE I

COST OF SEWAGE TREATMENT AT BALTIMORE

Year (1)	Average Sewage Flow M. G. D. (2)	Population Contributing Sewage[1] (3)	Fixed Cost: Total Cost of Plant (4)	Fixed Cost: Interest 4.1% Plus Depreciation 1.5%[2] (5)	Fixed Cost: Per M. G. of Sewage (6)	Fixed Cost: Per Capita per Year (7)	Operating Cost: Total (8)	Operating Cost: Per M. G. of Sewage (9)	Operating Cost: Per Capita per Year (10)	Fixed Cost and Operating Cost: Total (11)	Fixed Cost and Operating Cost: Per M. G. of Sewage (12)	Fixed Cost and Operating Cost: Per Capita per Year (13)
1921	46.62	536,952	$3,337,100	$186,877.60	$10.98	$0.348	$ 76,656.02	$4.51	$0.143	$263,533.62	$15.49	$0.491
1922	47.49	556,400	3,344,100	187,269.60	10.80	0.337	106,384.26	6.14	0.191	293,653.86	16.94	0.528
1923	48.17	578,755	3,496,000	195,776.00	11.14	0.338	103,983.21	5.91	0.180	299,759.21	17.05	0.518
1924	53.50	608,127	4,027,600	225,545.60	11.52	0.371	106,945.52	5.46	0.176	332,491.12	16.98	0.547
1925	55.09	647,080	4,257,800	238,436.80	11.86	0.368	108,048.90	5.37	0.167	346,485.70	17.23	0.535
1926	58.54	681,962	4,392,400	245,974.40	11.51	0.361	103,399.73	4.84	0.151	349,374.13	16.35	0.512
1927	59.62	702,827	4,584,000	256,704.00	11.80	0.365	104,418.00	4.80	0.149	361,118.00	16.60	0.514
1928	63.49	714,032	4,601,900	257,706.40	11.09	0.361	107,632.79	4.63	0.151	365,339.19	15.72	0.512

[1] Estimated as of July 1.

[2] Depreciation based on a useful life of 33 1/3 years.

TABLE II

COST OF OPERATING THE BALTIMORE SEWAGE WORKS

No.	Treatment Unit	1921	1922	1923	1924	1925	1926	1927	1928
1.	Bar screens	$ 5,469.19	$ 5,544.34	$ 4,571.48	$ 5,454.52	$ 5,790.73	$ 6,207.70	$ 6,119.19	$ 5,928.62
2.	Settling tanks	8,974.66	11,733.60	16,944.95	17,372.38	17,231.64	16,880.86	18,650.84	21,205.66
3.	Imhoff tanks	4,822.11	3,640.52	3,536.68	2,896.14	.....	.....	.....	.....
4.	Revolving screens	10,987.67	13,289.15	13,518.24	10,694.38	13,171.15	8,809.55	9,184.28	4,898.37
5.	Trickling filters	11,500.72	16,599.40	12,602.55	16,247.69	13,483.48	15,583.68	13,608.66	14,276.39
6.	Final settling basins	3,491.19	3,437.87	4,972.45	5,190.52	4,287.61	3,805.83	4,307.50	3,793.64
7.	Sludge digestion tanks	8,057.62	9,534.16	12,780.20	14,187.11	16,078.24	13,122.31	10,891.97	11,318.71
8.	Sludge drying beds	13,262.19	18,181.37	23,300.63	23,558.90	23,601.03	25,001.21	25,311.14	24,099.49
9.	Final sludge disposal	2,090.67	16,331.68	506.38	.....	.....	2,561.34	4,242.99	7,643.39
10.	Maintenance of grounds	8,000.00*	8,092.17	11,159.65	11,343.88	14,405.02	11,427.25	12,101.43	14,468.52
	Total	76,656.02	106,384.26	103,983.21	106,945.52	108,048.90	103,399.73	104,418.00	107,632.79

* Estimated.

TABLE III

PERSONNEL OF THE BALTIMORE SEWAGE WORKS

Title	Number Employed	Salary
Supervising Force		
Superintendent	1	$2800 per yr.
Chemists	4	$1600 to $2500 per yr.
Clerk	1	$1600 per yr.
General Operating Force		
Foreman	1	85c per hr.
Operating engineer	1	$1800 per yr.
Sewage sampler	1	50c per hr.
Storekeeper	1	50c per hr.
Janitors	2	30c and 45c per hr.
Watchmen*	2	45c per hr.
Laborers	12	45c per hr.
General Maintenance Force		
Machinists	2	75c and 80c per hr.
Electrician	1	$1900 per yr.
Carpenter	1	70c per hr.
Chauffeur	1	50c per hr.
Helpers, handymen, etc.	5	45c and 50c per hr.
Bar Screens		
Laborers*	2	50c per hr.
Settling and Sludge Tanks		
Laborers	10	45c and 50c per hr.
Revolving Screens and Trickling Filters		
Operating Engineers	4	$1500 to $1600 per yr.
Laborers*	2	45c per hr.
Sludge Drying Beds		
Foreman	1	65c per hr.
Locomotive operator	1 to 2	50c per hr.
Laborers	10 to 22	45c per hr.
Final Sludge Disposal		
Crane operator	1	55c per hr.
Maintenance of Grounds		
Laborers	2 to 8	45c per hr.
Total	69 to 88	

NOTE: Supervising force works 38½ hrs. a week. Remainder of personnel works 48 hrs. a week except as noted.

The salaries paid during 1928 totaled $89,186.55.

* Work 56 hrs. a week.

Since the principal item of expense in operating the plant is labor and supervision, the personnel and their salaries are given in Table III. There is usually little fluctuation in the number of employees except in the number of laborers employed to remove sludge from the drying beds and to main-

tain the grounds. With reference to the former group as many as three gangs are needed at times, with ten men in a gang, exclusive of the foreman and the operator who drives the locomotive. During the spring and fall, however, one gang is sufficient. The maintenance of the grounds, which consists mostly of cutting shrubbery and grass, frequently requires the services of from two to six men.

The cost data compiled at the Baltimore works have been of great value as a basis of comparison with the cost of other methods of sewage treatment, especially where these methods have been considered for adoption at the Baltimore plant. Similar costs, compiled at other sewage works, should prove useful to engineers and others who are interested in sewage treatment.

Standardization of Costs in Sewage Treatment Works Operation[1]

BY GUS H. RADEBAUGH[2]

Records of costs of operation of sewage treatment works are of vital importance, in my opinion, with regard to the successful future of the subject in which we are so much interested.

It is not my desire in this short paper to present methods of cost accounting that can be used and adopted in the management of all treatment works. I do appreciate, however, that the engineering profession and the industries associated with this problem will be penalized by a public which is desirous of clean streams, better health and a keener respect for the great out-of-doors, if this group and similar organizations neglect the importance of a standardized national code of cost accounting for the construction and operation of sewage treatment works.

It is my opinion that community progress comes only to those municipalities which are fortunate enough to accept correct and economical design of public works, and which have public leaders who believe in and see to the intelligent expenditures of public monies. This and similar associations can do much to encourage and assist in establishing correct standards for our community leaders to follow.

Many of the citizens of the State of Illinois have awakened to their individual responsibility with relation to the pollution and destruction of the state's beautiful rivers, and are accepting the challenge of civilization by proper disposal of sewage and industrial wastes. Illinois has 22 sanitary districts organized under the Law of 1917 and 2 districts organized under special acts, the Chicago and North Shore Districts. It is established that 135 cities and towns in the state are recognizing in some manner the importance of treating their waste.

The Urbana and Champaign Sanitary District, organized May 24, 1921, was the fifth municipality in the state to take advantage of the Law of 1917. This District consists of a rectangular area with a maximum width of 2.5 miles and a length of 4.0 miles. The total area within the Sanitary District is 5456 acres or 8.53 square miles. The total population is now 38,540. The density of population for the District in 1930 is estimated at 6.4 per acre; by 1960 this may increase to 12.8 per acre. The present assessed valuation is $27,150,053.00. A $500,000.00 bond issue was voted November 28, 1922. The total sewage treated the past four years is approximately 5,346,000,000 gallons, an average of 1,336,525,000 gallons per year, or 3.66 million gallons per day.

[1] *Read at Second Annual Meeting, Central States Sewage Works Association, Indianapolis, Ind., June 21, 1929.*

[2] *Manager, Urbana-Champaign (Illinois) Sanitary District.*

A complete report covering operation and management of the District's affairs has been published annually, giving to the tax payers a financial history of the operation of their project. A yearly audit is made of the income and expenditures by a public accountant.

In designing the cost accounting system used by this District several standards were established as essentials in maintaining an accurate record. These essentials were:

1—Any system used should be substantiated by the budget method of financial control.

2—The system used should make possible without excess labor a monthly operating balance sheet.

3—All expenditures should be properly charged to accounts as established by the tax levy ordinance.

4—The tax levy ordinance should be divided into specific accounts and amounts—thus

B-2	Employee's wages	$00.00	B-4	Water.....	$00.00
B-3	Power and coal...	00.00	B-8	Grounds.....	00.00

5—Voucher checks must be signed by two officers of the Board and the Treasurer.

6—No account should be paid unless an itemized invoice is issued to the District covering the item of expense.

7—A yearly certificate of audit must be received by the Board from a public accountant.

With the above essential as the guide, the following is the adopted accounting program:

The Treasurer of the District, under $50,000 bond, receives the monies collected from the levy by the County Treasurer and deposits same in the District's depository. The Treasurer makes a monthly report to the trustees of receipts and expenditures.

The manager receives the invoices for payment, arranging them into the proper accounts as established by the tax levy. They are then presented to the board at a regular meeting for approval or rejection. When the approval is made and the authorization is made a part of the minutes of the board meeting, a voucher check is drawn in favor of the invoice, the number of the check being entered on the invoice, it then being filed for audit. The check is signed by the President and Clerk of the Board and by the Treasurer. The Treasurer makes the entry in a distributional ledger. The manager enters the paid accounts under the proper distribution. The manager also presents to the Board a monthly appropriation analysis or budget control sheet, which shows at a glance the working balance of the various accounts, expenditures this month, expenditures to date, appropriation unexpended, total account balances and the bank

balances for the month. This monthly appropriation analysis has been found to be of paramount importance in the proper control of all expenditures. The accounts of this District have the following headings:

FOR INTEREST AND BONDED INDEBTEDNESS

A-1	Interest due and payable June 1, 1929.....	$00.00	A-2 Interest due and payable Dec. 1, 1929..... $00.00
	A-3 Principal payment due and payable Dec. 1, 1929....$00.00		

FOR OTHER CORPORATE PURPOSES

B-1	Salary of Ofc. & Atty. Fees.	$00.00	B-6	Supplies & New Equip.....	$00.00
B-2	Employee's Wages.....	00.00	B-7	Lab. & Ofc. Exp.....	00.00
B-3	Electric Power & Coal.....	00.00	B-8	Ground Maintenance.....	00.00
B-4	Water.....	00.00	B-9	Secondary Sett. Tank.....	00.00
B-5	Repairs on Equipment.....	00.00	B-10	Contingencies.....	00.00

The District's published reports show the following cost data:

COSTS PER CAPITA

	1925–26	1926–27	1927–28	1928–29
Operation	$0.42	$0.48	$0.35	$0.38
Total.....	1.74	1.62	1.54	1.53

These figures represent all expenditures passed for payment by the Board of Trustees such as bond interest, bond retirement, new construction, engineering fees, legal costs, plant operation labor, etc., in fact every expenditure incurred by the District.

Conclusions

The general public demands correct and standardized cost accounting for sewage treatment works.

In the opinion of many engineers cost comparison of works operation is at the present time difficult due to the varieties of interpretation of operation costs.

The strongest force tending to stimulate construction of sewage treatment works is the intelligent and honest management of those already in operation.

In my opinion the Izaak Walton League of America and the American Public Health Association have done more to prepare the public for the acceptance of correct sanitation than all other agencies combined.

With the above conclusions as my forerunner, I respectfully present to this convention this recommendation:

"That this organization recommend to the officials of the Federation of Sewage Works Associations that a national committee be developed to standardize a national code of cost accounting adaptable for sewage treatment works operation."

The Sewage Situation in California[1]

BY C. G. GILLESPIE[2]

The preparation of this paper has been a review, or inventory as it were, of facts showing highly encouraging tendencies here in California toward more extensive sewerage and better sewage disposal. It is evident that in less than fifteen years sewage works have become a major civic activity and disposal is becoming one of the civic virtues. The full truth of this stands out when comparison is made with the status of practice as the Bureau of Sanitary Engineering found it, when created thirteen years ago by the State Board of Health.

Popularity of Sewage Works

We take it as a matter of course nowadays that plumbing has passed as a luxury. This fact, above others perhaps, shows why the building of sewers and improving sewage disposal has speeded up faster than population growth. Places of smaller and smaller size have found it necessary to build sewers until now public systems are not uncommon in communities of 500 or 600 people.

It appears from a reasonably accurate survey, which seemed necessary in the preparation of this paper, that the net increase of cities and towns was from 260 to 268 for the years 1922 to 1928, and the net increase in governmental units and institutions has been but 20 in the past six years. Yet there have been at least 56 communities that have installed whole systems of public sewerage in that time. Forty-five of them have incorporated sewage treatment at the outset and nearly half of the treatment plants are high grade, producing a stable, oxidized effluent. Only seven of the older places have added treatment works in the past six years and one of these is for producing an oxidized effluent. It is indeed true that the new and younger communities are setting the pace in sewage sanitation.

Total cities, towns, sanitary districts and public institutions are shown by the survey to have increased at a rather steady rate from, roughly, 244 in 1913 to 303 in 1923, and 338 at present. Well over half of them fall in the range of 1000 to 5000 population. About 10% are under 1000, a little less than 20% are between 5000 and 10,000 population. Our problems are therefore essentially those of the small town.

The percentage incidence of public sewers in the whole list was in 1913—62.5%; in 1923—76.5%; at present 85.5%. If the curve means anything, universal sewerage will arrive in California within another generation.

[1] *Paper discussed on evening of Monday, June 17, 1929, Sanitary Engineering Section, University of Southern California School of Citizenship and Public Administration, Short-Course, 1929.*

[2] *Chief, Bureau of Sanitary Engineering, State Department of Public Health.*

Impetus to Sewage Treatment

Sewage treatment has shown a slower but nevertheless steady growth. As just remarked, it has been exceedingly rapid in the recent sewerage systems. The statistics show that of all the localities with publicly owned sewers, 64.5% had some form of treatment in 1913. It was almost always a crude attempt. In 1923 the percentage was 66.5 and at present it is 70.2, and the grade of plants is much better. The increase is not great but is sufficient to be heartening.

Nearly all that is best in sewage disposal here is the work of the past fifteen years. In 1913 less than five per cent of the plants even pretended to produce a final or oxidized effluent. In 1923 the percentage had increased to 10.3, and at present practically one-fourth of the plants are designed to produce an oxidized effluent. The period prior to 1913 may in fact be classed as the septic tank era; the period 1913–1923 as the Imhoff tank era; and now we are getting into a period where, without exclusion of the older methods, marked diversity of plants appears and higher degree of treatment is becoming the rule, suited to the particular situation.

There were but four schemes of sewage treatment in use in California in 1913, whereas the present survey shows at least thirteen major variations. The survey shows that there are now 9 fine-mesh screening plants serving 31 different plants; 77 septic tanks, mostly relics of the past, serving 66 places; and 83 Imhoff tanks serving 85 places. There are also 5 separate sludge digestion layouts of recent design serving one city each. Four of the septic tanks and Imhoff tanks have been made to use the principle in a rather makeshift way.

Of the higher grade treatment works, practically unknown here sixteen years ago, we now have 33 sprinkling filters serving 30 places, and 6 activated sludge plants used by 21 places, exclusive of large areas of unincorporated territory. There still remains an old contact bed of four originally built. Four places employ chlorination for odor control, and 12 plants serving 18 communities employ it for sewage disinfection. In addition, four fine-grain filters serve two places. Two cities employ sewage ponding to obtain oxidation and practical disinfection equal to that of a sprinkling filter through use of the principle of long-time storage exposed to sunlight and air. Pasadena and three partner cities produce high grade fertilizer at their activated sludge plant.

As yet we have no instances of gas collection and heating of sludge or greenhouse drying of sludge, but designs are in progress. There is one case where an activated sludge plant precedes a sprinkling filter. All in all, California has adopted practically everything that has appeared on the horizon for sewage treatment.

None of the figures heretofore given extend to other than cities, towns, districts and public institutions, where local authority exists for obtaining public sewage works. As a matter of fact there are fully three dozen sewer systems of a private nature which are of small-town size, and most of them have sewage works that will compare in completeness with anything the cities have built.

Joint Sewerage

A large part of the recent inauguration of sewage and disposal works is attributable to a number of extensive joint sewerage projects, undertaken particularly in the South. The arrangement is essentially contractural and the result of it is to bring the sewage of many communities to central points for treatment. It is difficult to appraise adequately the importance of these huge centralizing projects in their localities and to the state unless one contemplates what the situation would have been without them. Sanitation and development would have been next to impossible.

Among these joint projects may be mentioned, first, the Los Angeles County Sanitation Districts which embrace thirteen cities entirely, parts of three others, and contemplate the inclusion of ten more within the next few years. At present the common sewage of ten of them is treated in an activated sludge plant and released to a fresh water slough. Before long it will be necessary to convert the plant to settling works and convey the effluent into Pacific Ocean 5000 feet off shore. This is the ultimate plan that will serve upwards of 2,000,000 people.

Los Angeles City itself, with a large screening plant, takes care of some six other cities besides two Sanitation Districts, and one more city is to be included shortly. The sewage is disposed of into Pacific Ocean in an endeavor to prevent damage to recreational beaches.

Pasadena with its activated sludge plant has for years taken care of three other cities and disposes of the effluent in part on land and in part to a river which is essentially a drainage way. Pomona's activated sludge plant serves two other communities under contract and sells the effluent to orchardists. Orange County joint outfall serves eight cities and sanitary districts and disposes of a screened effluent into Pacific Ocean.

State Typhoid Situation

Typhoid decline has been highly gratifying. The death rate per 100,000 has decreased from about 15 in the year 1915 to about 2.4 last year. In fact there is nothing in the present typhoid record that connects it with inadequate sewage disposal. It must be admitted, however, that it is difficult for a sanitarian to see why this should be so when he views some of the sewage eyesores around the state.

The Raw Sewage Situation

Looking to the horizon there are just two really dark clouds in an otherwise fair sky. One is the lack of preparation of the state to take on industrial expansion, which is upon us, without aggravation of sewage disposal difficulties; and the other is the way the practice of raw sewage disposal survives in the older communities in spite of changes in conditions which are making it more and more untenable. It is one of those relics that have been inherited from the state's youth and that seems, unfortunately, to have become time-honored with particular ease.

The survey shows there are approximately 105 cities that fall in this class, representing nearly one-third of the state's population. Perhaps eight of these communities can give as an excuse that their industrial wastes prohibit sewage treatment. As for the remainder, the only conclusion I can offer for not even a stir of agitation for a change is indifference of their citizens to present offense and still less regard for future consequences.

Most of these 105 cities are to be found in three rather distinct regions—the Mother Lode of the Sierras; the belt along the rivers of the Great Valleys; and the harbors from one end of the state to the other.

Among them 23 public sewer systems, not to mention many non-publicly owned systems, are now polluting fresh waters with raw sewage and eight of these bodies of water are either unquestionably of value for domestic supply or are actually in use for that purpose. Nine of the polluted streams are valuable for irrigation and recreation; six are drainage ways, which, however, carry water ultimately redeemable for use. In addition to these 22 systems disposing of raw sewage, there are about twice as many, 41, which though they use some treatment, nevertheless entail fresh water pollution almost equal in seriousness to that by the first group.

The survey shows that 67 of the sewer systems sewer raw sewage to salt waters, 37 being bays and harbors; 25 are sloughs; and five of the systems run raw sewage to the ocean. Forty-one run partially treated sewage to salt water, the ocean being the principal recipient. Most of the ocean outlets would be considered to cause no pollution, so successfully have the projects been worked out.

Fifteen sewer systems of the state run raw sewage onto land and 61 treat the sewage to some extent ahead of the land disposal. In the past six years, in spite of the impetus to sewage treatment, pollution of fresh potable water by raw sewage has increased by two, salt water by eleven and land by four.

This situation, especially as it relates to raw sewage, is too foreboding to pass over without some further deliberation. I do not know that the mere thought of disposal of raw sewage need be so reprehensible for, as a matter of fact, the actual results in some instances are far superior to those

in some other cases involving sewage treatment, acceptable under the conditions. But nine times out of ten, disposal of raw sewage represents the lazy way and the unenterprising way of passing the sewage along. And so when the inevitable day arrives to treat the sewage, the history of sanitation within the state shows these to be the most refractory cases with which the sanitarian has to deal. Conversely, once a community puts in sewage treatment, no matter how meager, it has been a psychological truth that the people there are ready for further sewage treatment when plausible reasons appear.

It needs no stressing that the ultimate result of raw sewage dumping, or for that matter any makeshift disposal, is destruction of public and private resources, and more or less menace to health. An effective bar is thus set up against industry and state development far out of proportion to the cost of avoidance. That is why, it seems to me, that those minds that are framing the destiny of the state should look with considerable alarm on tendencies away from sewage treatment or that lead to perpetuation of the present eyesores.

The subject is not one which regulating authorities, local or state, can materially control or affect, except through such utterances as these and an occasional personal appeal. The State Board of Public Health for instance can only hold out for minimum sanitary requirements which are clearly set down in the law. To insist on more than the law pretends to secure simply builds up opposition to the worth-while things the Board can do, and so nullifies its usefulness to the state. The problem therefore comes back to the people themselves, their sanitary engineering advisers and leaders of public opinion, to steer constantly away from propositions involving a crude sewage disposal, at least where careful prediction shows such a practice is not tenable rather indefinitely. The danger is that this state, like others, will eventually find itself in a mire of sewage difficulties from which extrication will be most trying. We shall find ourselves totally unable to fulfill the conversion from agriculture to industry. Sewage treatment, taken in time, need not be always complete or expensive, but an intelligent long-time analysis of the requirements is always in order because it leads to comprehensive planning and its progressive fulfillment.

Practice and Tendencies in Choice of Disposal

The accompanying table gives rather succinctly a fairly accurate picture of the present practice of sewage disposal in this state.

After deducting for the Joint Disposal projects in the South, which are so unusual as to distort tendencies, certain conclusions appear to stand out.

(1) There is but little extension of the practice of further resort to drinking waters, stream or recreational waters for disposal. Furthermore, complete sewage treatment for the latter class disposal is increasing. There

is also a very strong tendency to turn to land disposal with more or less sewage treatment. This, of course, is ideal from the standpoint of stream protection. Probably next safest for public welfare in the inland communities is to sewer to drainways. It is evident that this practice is increasing and is being made all the more tenable by recourse to complete sewage treatment.

(2) The extension of the disposal of raw sewage is most common in the case of salt water sloughs. Two-thirds of the new disposal projects involving raw sewage have been to salt water outlets, of which about one-half have been sloughs.

(3) The use of preliminary treatment has been confined principally to outlets on land or into salt water. Final treatment has been most applied, at least in the last six years, to the outlets into fresh water, and next in order to the land disposal outlets. There are no instances of final treatment applied to salt water outlets.

SUMMARY OF SEWAGE DISPOSAL CENSUS IN CALIFORNIA AS OF APRIL 1929

Includes All Systems Known to Us Administered by Public Authorities

	TOTAL PUBLIC SYSTEMS				INCREASE SINCE 1922			
Disposal to:	Total	Raw	Partial Desludged Effluent	Stable Effluent	Total	Raw	Partial Desludged Effluent	Stable Effluent
FRESH WATERS—Total	100	23	41	36	35	2	5	28
Class A—Potable	20	8	9	3	6	2	2	2
Class B—Irrig. and Recreation	28	9	11	8	7	0	1	6
Class C—Drainage	43	6	16	21	19	0	1	18
Class D—Intermittent streams	9	0	5	4	3	0	1	2
SALT WATERS—Total	108	67	41	0	41	11	30	0
Bays and harbors	44	37	7	0	6	3	3	0
Ocean	34	5	29	0	24	2	22	0
Sloughs	30	25	5	0	11	6	5	0
LAND—Total	92	15	61	16	38	4	23	11
TOTALS	300	105	143	52	114	17	58	39

(1) Total no. of different places having sewers = 288.
(2) Total no. of sewer systems (each class of disposal per city = 1) = 299.
(3) Total no. of different cities having sewage treatment = 202.
(4) Total no. of sewer systems (3) having treatment = 205.
(5) Total no. of places without public sewers = 50.
(6) Total places = 288 + 50 = 338.

Abatement of Stream Pollution

Some progress has nevertheless been made in the abatement of stream pollution in the last six years, but the most serious offenders are still deep rooted. Creeks and rivers have been freed of sewage at Vacaville, Arroyo Grande, Paso Robles, Yreka, Patton State Hospital, Reedley and Compton.

Pollution has been reduced at Walnut Creek, Truckee, Sonoma State Home, Dunsmuir, Sonoma, Boulder Creek, Lodi, Weimar Tuberculosis Hospital and Shastina Sanitary District.

Pollution has been added during the last six years at Corning and at North Sacramento. In both cases there was no alternative without confiscation of an industry in one case, and doing without a sewer system in the other. Neither should prove a healthy excuse in future.

Technical Status of Sanitary Engineering

Until the last few years, sanitary engineering in the state has been distinctly along stereotyped lines followed throughout the country, modified to some extent in details according to certain ideas of the designer. It is regrettable that up to the last two years the "turnover" in sanitary engineering advisers has not been great. Men were drawn to it by necessity or the intrigue of it, the subject seemed so easy. Usually in four or five years the real complexity of the problems and inadequate return caused most of them to drop out. Other engineers stepped in to begin the cycle over again.

We are at the widening of the ways, where still greater possibility and economy can be worked through care and ingenuity in applying fundamental principles of sewage treatment. However, this requires that the principles be particularly understood and that is something of slow acquirement.

I believe there is no doubt but that the state will be better served if it can encourage and properly compensate a few design engineers to remain in the field and properly master its intricacies.

In the main we have not suffered from extravagance in the extent of treatment, but I also think it is a fair comment that, except for the larger Joint Projects, the projects have not been as well laid out along comprehensive lines, adjustable to future extensions and requirements, as would best serve the public interest. On the other hand, I cannot think of a case where the scheme of treatment has been unnecessarily advised in the light of prevailing knowledge at the time. Several towns have abandoned all or parts of plants but it is safe to say that, with possibly two exceptions, these communities have notably lowered the sanitary tone of their disposal to an undesirable degree.

Operating Personnel

The operating personnel of sewage plants around the state has not advanced as the complexities of the problem and the responsibility require. On the other hand, in three recent meetings or conferences of sewage works operators held by the California Sewage Works Association, the calibre of men who are taking an interest in this subject is most outstanding and it

augurs well for the future. So far expert technical supervision has not been appreciated in California. Here again I look for the California Sewage Works Association to exert a powerful influence. Their discussions are bound to clarify the nature of the problems and demonstrate which of the problems yield only to the attack of the technical men.

Plant Isolation

The tendency of years past to ignore isolation on the one hand, and on the other to seek vainly for permanent isolation, is gone. As a rule good foresight is being shown in getting sites well beyond town development and much thought is being given to locate as far as possible from neighbors. The engineers are trying to analyze the odor-production tendencies of the sewage and estimate odor travel from sites under consideration.

Beautification

Beautification of sewage disposal plants in the state is entirely a new idea. Pasadena alone has gone far in it. The surroundings are a credit to any sewage plant in the country. Within the last few months, however, induced very largely by the new California Sewage Works Association which has caused operators to make comparison between plants, planting of shrubs and flowers is being done in several places. I look for operators to vie with one another in the future in making their plants impressive.

Industrial Wastes

Everyone seems to feel that the state is on the verge of industrial expansion. At present the principal industrial wastes with which the sewage works have to deal here are those of agriculture—canneries, milk plants, sugar factories and olive pickling works. There are also instances of trouble caused by paper mill wastes, tanneries and gas plants. Great damage still is being experienced in sewage disposal where these wastes exist. The situation is so acute that sewer systems have been held in abeyance in some instances, and the people there still use their cesspools. The present way of facing the problem is to dodge it. The general result of the policy so far is that there are not a few eyesores on land, streams and waterways.

Reedley, Kingsburg and Lodi run their cannery wastes, raw, to valuable rivers and channels through special industrial sewers, forming great masses of ugly slime and deposits in the stream.

Turlock, Modesto and Corning practically abandoned treatment, and now pollute valuable waters. In the harbors of the state there are also several distinctly industrial waste pollutions that are notorious.

Of the cities doing the most to handle industrial waste satisfactorily, Ripon has established a separate line for a milk plant, which runs the waste

onto a piece of land before putrefaction has set in. A milk plant in Wasco and the City of Tulare have a somewhat similar arrangement, but in these cities chlorination is used with great success as an odor retardant. Selma and Tulare use their storm sewers for industrial sewage, accompanied by land disposal. Pomona by-passes its worst wastes around the activated sludge plant to an isolated piece of land.

Sewage Research

For a number of years a small group in California has been striving to get state aid established for sewage research under the State Department of Public Health, for it must be apparent from this paper, which has made no particular point of the difficulties of sewage disposal, that there is much need of a more scientific understanding of the principles and the processes of sewage treatment. As the efforts of these men stand today, April 22, a bill for $20,000 a year is pending before the State Legislature with good prospects for passage.

[EDITOR'S NOTE: This bill was unfortunately vetoed by the Governor.]

Financial

In recent years financing construction of sewer systems is being done to a considerable extent by district assessment. In some cases, provided the community owns the land required for the outfall and disposal, whole projects have been put in in this way. In most cases, however, the outfall, treatment and disposal works have been financed by a bond issue submitted to the electorate. Under the state law the maximum amount of bonded indebtedness of most cities for all purposes is 15 per cent of the assessed valuation. In the case of small growing communities the building of sewer systems is particularly handicapped through this limitation. Maintenance, too, has been a serious problem in most communities through the necessity of meeting operation costs out of current revenue and tax receipts. Under the state law there is a one dollar tax limit for general expenses. In communities with considerable outside revenue, operating expense is not so difficult to meet, but in the other communities it seems apparent that special allowance will have to be made to meet operating costs or the communities will not be able to discharge their obligations in the neighborhood of disposal, of avoiding much injury and damage. So far legal inhibitions to passing an enabling act to raise the limit for the sake of sewerage have been insurmountable.

Public Supervision of Sewers and Sewage Disposal

In 1907 the legislature passed an act commonly known as the Public Health Act for the purpose of preventing the establishment of sewage disposal which might become a nuisance or menace to health. In its operation

the Act leaves the supervision to the discretion of the State Board of Public Health which, under the law, is required to grant or deny permits for sewage disposal. The Board has administered the Act in a spirit of cooperation with the communities to be supervised, and I think the genuineness of this coöperation more than anything else is responsible for the development of the keen neighborly conscience on the part of the sewering communities toward those who may be injured.

There are no set standards of sewage disposal. Each case is considered on its own merits. Though the Board has seldom obtained all the results that would seem desirable, it has accomplished a remarkable improvement in the status of sewage disposal, and it has quite steadfastly refrained from being a party to inexcusable conditions which it could possibly correct under the Public Health Act.

In recent years, with the relative decline of available state supervision, more and more of the burden of public supervision is falling upon the counties. As yet their health departments have not been provided with adequate personnel to replace state supervision. We are anxious to see continued the same spirit of concert between the supervising authorities and the communities, regardless of the supervisor, and we feel that it calls for the use of sanitary engineers within the county health departments who are so well trained that the advice they can give proves sound and helpful. The relationship of the state to these county engineers should, in turn, be one of coördination and coöperation. In discussing this kind of set-up with some of the local community officials, I gather that they fear county supervision might prove arbitrary. The same fears were felt when state supervision was first put forth. I feel certain that if the counties are careful in the selection of well trained men of good judgment, county supervision should prove smooth and helpful. Certainly it would be a mistake to entirely forego some outside stimulus of operators and supervision of sanitary works of this kind which affect so large a public. For, as someone once said, sewage flows downhill without regard to boundary lines, and germs have no sense of geography.

An Acknowledgment

I fear we may forget that the seeds of sanitary engineering as a science were not planted in California until Benjamin Ide Wheeler, then President of the State University, brought Professor Charles Gilman Hyde from the East in 1905 to establish the course here. I often think what an intrepid spirit those first years in better sanitary engineering in the West must have required. The story of the skeptics who had to be talked down would make an interesting story in itself.

Sewage disposal has had to "pull itself out of the cellar" in baseball parlance. There was a time, before sewage works became a throbbing

civic activity, when it was difficult to obtain a chance to demonstrate that the job can be done with remarkable freedom from offense. The word "sewage" has been more or less nauseating. The thing therefore worked in a vicious circle, for with nothing better afforded than septic tanks and sewer dumps, sewage WAS nauseating. That is why we should "hats off" to those who, against great adversity, pioneered better sewage treatment in this state.

There is Mr. R. V. Orbison, now City Manager of Pasadena, who brought the activated sludge idea to a reality in his city, after years of uphill work against human and technical obstacles that would have disheartened most men.

I wonder, too, if we fully realize that right here in Los Angeles County, Mr. A. K. Warren, Chief Engineer of the Los Angeles County Sanitation Districts, has succeeded against trying odds in establishing centralized sewage disposal for the scores of towns bordering the city proper, that their own development may not be retarded or diverted through insanitation. That is a big accomplishment. We are too near the scene of action to realize its worth. As the years move us farther away, certain events become milestones and certain men loom as personalities of progress.

But let us not forget that we are all still pioneering in this field of sanitation and making the world a cleaner and safer place in which to live and work. I take it that is why we are here today—to pick up bits of knowledge and bits of encouragement.

What follows in this paper relates especially to random, intimate observations and experiences with the various components of sewage disposal works and may be somewhat meaningless to any but the engineer and operator. However, the story is hardly complete without reference to the technical progress and practice.

SUPPLEMENT, GIVING A FEW EXPERIENCES WITH SEWERS AND TREATMENT WORKS IN CALIFORNIA

Combined Sewers

For the main part, combined sewers are confined to cities of the Gold Rush days—San Francisco, Oakland, Sacramento, San Jose and by some chance, Berkeley. I doubt that such a system would now be advised in any of these cities if they had a chance to make a fresh start. Some of them are now unloading storm water to nearby waterways and are thus gaining capacity for further sanitary sewage.

Pumping Sewage

In the past six or eight years centrifugal pumps have been greatly improved in their adaptation to pumping raw sewage. The survey, probably

quite incomplete in this regard, shows at least sixty cities now pumping their sewage. Pumping sewage is not to be shied at, as it was not so long ago. In many cases pumping has made possible the building of sewage works otherwise impossible.

Flat Grades

This topic was highly debated at a recent conference of sewerage engineers and operators of the state, held at Fresno. Several Valley cities related their experiences with sewer grades far below those advocated in the text books and their experiences were to the effect that stoppages are not common, and furthermore, the cost of removal was far less than would have been the additional annual costs for a sewer system constructed along accepted practice. In many cases the use of the flat grades was positively essential to having a sewer system.

However, other engineers deplored letting down the grade standards. It seems to me that the experiences have established the permissibility of grades more nearly flat than the text books call for, and the engineering job is now to find a closer determination as to just when such flat grades can safely be used. Undoubtedly storm waters, silt-leaking sewers, and possibly some precipitating trade wastes operate to compact sewage and argue for the steep grades. On the other hand, conditions that promote a fluid sludge may have an opposite effect. Other factors to be considered are the putrescibility of the sewage, line odors and disintegration, which may prove important in certain instances. These are a few hints to show that even in sewer building we have yet to apply greater refinements and less empiricism in the calculations.

Grit Basins

So far as I know, the use of grit basins is unknown in California and their omission has not made itself felt, perhaps because we have no treatment of combined sewage.

Oil Skimming

There is no particular provision in the plants here for oil removal except by manual effort and some attempt at curbing discharge of oil and crankcase waste into the sewers. Serious operating nuisances result for the operator and it seems that sludge may be rendered unusually liquid by these oily wastes. In the case of ocean outlets, oil produces noticeable sleek fields. There are tendencies to develop uses for crankcase oil and to design better types of oil burners which will not waste oil to the sewers.

I am moved to remark that there are probably not a few difficulties in sewage disposal, especially from the industries, that will in time be eliminated at the point of origin, rather than at the point of treatment.

Fine Screens

There are a couple of old disc type screens still in use but the drum type has appeared to be more satisfactory. Disposal of screenings has not been solved. Long Beach incinerates them; Lodi and Pasadena bury them, but the other plants simply dump the screenings on the ground in a most insanitary fashion. No one has tried digestion of screenings in California.

Imhoff Tanks

This design of settling tank has quite fully met expectations for the removal of settleable solids but it has not fully met expectations for the delivery of fresh, odorless effluent in those cases where the sludge itself was odor-producing. The reason for this appears to be that odors in the sludge compartment, though theoretically confined to the lower chamber, actually pass upward with currents induced by temperature, baffles and by operations that cause the water level to rise and fall. To some extent it may be due to failure to remove solid accretions from the flowing-through chamber, or to hydrogen sulphide formation in the settling compartment; but I am inclined to believe the former explanation is more important.

Scum formation and foaming have proved to be much more onerous and expensive to combat than was expected. We have surely underrated the significance of certain wastes, like soaps and grease-forming wastes, in this connection, and have not analyzed sufficiently the digestion space requirements for the least troublesome digestion.

In a recent survey of Imhoff tanks in Northern California, we were surprised to find extremely wide variation in the water content of the sludge, from as low as 4% to as high as 15%, and to find also that the digestion period for practical digestion in one case was nearer ten months than six months, which is ordinarily assumed. As nearly all Imhoff tank sludge compartments have been designed empirically on the basis, first, of .75 cu. ft. per person, then 1.0 and now 2.5, it is too much to expect that sludge compartments would invariably prove large enough. The Bureau is at present pursuing investigations to find the advantages in reduced odors and less costly operations through more prolonged sludge storage, and to discover if possible clues to the wide variation in sludges undergoing digestion.

Separate Sludge Digestion

The principle of separate sludge digestion has shown itself to be sound. In the case of Tulare it made possible an inoffensive disposal of effluent on land where a septic tank effluent had previously made an unbearable nuisance. The offensive problem is the sludge, and separate sludge digestion puts the sludge in an enclosure where its damaging effects are localized. In the four plants in California, which are fully equipped with stirring

mechanisms, I have been struck by the ease and economy with which scum formation in the digester is kept down by the stirring.

Sprinkling Filters

These have been designed strictly on the basis of Eastern precedent without any analysis of permissible loadings under the varying climatic conditions of California. With the exception of Sonoma State Home, which has a soapy waste, the filters have worked with special satisfaction and appear to be exceedingly fool-proof and reliable. Filters are dosed by the use of fixed spray nozzles and dosing siphon. In one case, however, the variable head is obtained by pumping the applied sewage into a tapered head-regulating box, which has been modified in shape to create the proper distribution.

Final Settling Tank

Only one-half of the sprinkling filters use final tanks, in part as an effort in economy and in part because of information appearing a few years ago that the effluent of the filter was impaired in passing through the tank. From observation, final tanks are undoubtedly useful where a higher degree of clarification is required, and they become useful as a chamber in which chlorine may be applied, now that bacterial disinfection is figuring frequently in the requirements.

Activated Sludge Process

This is one of the sewage treatment devices of the last ten years. Among some engineers it is still of mooted value. They regard it as too costly to operate or too sensitive to sewage vagaries, and they regard its sludge problem as too difficult. However, what few troubles have been experienced here in California would have been hard to avoid by any present scheme of treatment.

In the case of one institutional plant, the laundry wastes made a cloudy but non-odorous effluent. Four of the plants suffered similarly and also suffered from sludge bulking when an unusual amount of cannery or milk waste was present in the sewage, but in all cases the activation of the sludge and clearness of the effluent recovered quickly. On domestic sewage, even with some cannery waste, the effluent and the process has produced a remarkable impression on visitors. Certainly the cost, considering the result, is not unreasonable. The sludge disposal problem has not been materially more difficult than experienced with Imhoff tanks.

The approach to the solution of sludge disposal has been from three different angles. It would appear that in the larger cities of 100,000 or over, the Pasadena plan of filtering and drying the sludge with heat, recovering fertilizer, with or without burning the exhaust gases, is the best plan;

whereas for the smaller cities and towns the method used at Pomona of digesting the sludge along with the Imhoff tank sludge is the simplest and most reliable. I think the Lodi plan of running the waste sludge direct, while activated, onto beds is more precarious. It also works at the Harbor City Plant of the Los Angeles County Sanitation Districts but failed at Pasadena because of nuisance.

Mechanical aeration by agitation has not given the same satisfaction in California as has the use of compressed air, in large part due to mechanical difficulties. We have both the Manchester type of bottom and the ridge-and-furrow bottom for air distribution. We have not seen a numerical comparison of efficiency, but from observation it would appear the Manchester type is the more efficient and logical. The plants here which have been in use for six years have been singularly free from filtros plate troubles.

Sand Filters

Sand filters, as used in California, are really a land disposal at high rate of application, in which the surface of the beds is cultivated but the beds are not cropped. Dosing is generally manual, visiting the works once a day. A few plants have siphon dosing tanks.

Oxidation Ponds

In the past two or three years a couple of cities have systematically developed ponds for oxidizing septic tank effluent. With ponds about 2 feet deep, and some care in proportioning the amount of incoming sewage to the size of pond so that a green or brown algae growth is maintained, oxidation proceeds forthwith, and within eight days a stability equal to that of an average sprinkling filter is obtained throughout the year. B. Coli removals are fully as high as by a sprinkling filter and in fact after about 16 days storage, a B. Coli count as low as 10 to 25 per cc. is frequently obtained. In clarification the effluent is not quite as good as that of a sprinkling filter. The investment cost is exceedingly low but operating costs to keep down weeds and occasional mosquito control probably result in a maintenance expense equal to that of a sprinkling filter.

Land Disposal

With the development of inland communities and the discouragement of stream pollution, land disposal is markedly increasing. About half of the land disposal areas derive revenue in the form of pasture and from that to intensive garden and orchard products, subject however to certain restrictions as to the kind of vegetables that can be grown in contact with sewage. Except in spots, the development of revenue has been unsystematic and has not at all measured up to the possibilities in this regard. A considerable number of "sewer farms" are mere dumping grounds for settled effluent.

As to the future, I look to see more high grade treatment added as homes encroach and with them we shall see intensive cropping. Here and there are instances of the potentialities. The little community of San Juan Bautista, for instance, disposes of every drop of its sewage for orchard irrigation, though a gully into which most communities would be tempted to dump the sewage runs only six feet away from the plant.

The City of Fresno had a unique problem in its land disposal, caused by the gradual saturation of the ground with sewage water which made a bog of it. The formation is a lens-like alluvium. The difficulty was overcome by sinking wells and putting in drainage pumps to dewater the substrata. Wells are in the neighborhood of 100 to 150 feet deep. The water pumped out of the ground is sparkling clear and practically B. Coli-free. In this way the city maintains the ground water plane at any desired level, usually six feet below the surface. It has been found that practically one-half of the sewage applied must be removed through underground drainage to maintain this level.

Sewage Treatment in Iowa[1]

BY W. W. TOWNE[2]

Iowa is primarily an agricultural state and as such has many small cities and towns relatively close together. The few large cities in the state are located either on the Mississippi and Missouri rivers or the larger inland rivers.

During the early development of these larger cities disposal of sewage by dilution into the streams caused no serious pollution problems, but at the present time all of the inland streams receiving sewage from these cities are becoming heavily polluted, with the result that the discharge of untreated sewage will have to be discontinued in the near future. At the present date only one city in Iowa with a population exceeding fifteen thousand has facilities for sewage treatment. Therefore the sewage treatment works in Iowa are comparatively small, the greater number serving municipalities between five hundred and five thousand population.

Most of the treatment plants are in municipalities having separate sewer systems and the sewage treated in the majority of cases is only domestic sewage. Extensive investigations have been carried on, however, in the treatment of creamery, packing house and sugar beet wastes, by Dr. Max Levine of Iowa State College and the engineering experiment station of that school. Using the data obtained there as a basis for design, a complete treatment plant for packing house wastes and two types of plants for the treatment of creamery wastes have been constructed in Iowa within the past year.

Although there are no authentic data as to the type of treatment first used in Iowa, it is safe to say that one of the first treatment works consisted of a septic tank. As the demand for a higher degree of purification increased the septic tank was followed by intermittent sand filters. This type of treatment was used almost entirely for several years, with various degrees of satisfaction. These plants were more or less successful mainly because of their small size.

It was some years after the advent of the Imhoff tank in this country before Iowa took to this type of primary treatment, and it was not until the last decade that Imhoff tank treatment has been used almost exclusively for municipal installations. For some years after the adoption of the Imhoff tank treatment and after trickling filters were replacing sand filters elsewhere, Iowa was still using the latter for secondary treatment. The abundance of sand found throughout the major portion of the state probably had some influence on the large number of sand filters.

[1] *Presented at Second Annual Meeting, Central States Sewage Works Association, Indianapolis, Ind., June 20, 1929.*

[2] *Assistant Engineer, State Department of Health, Des Moines, Iowa.*

The records of this department show that only four installations of contact filters are to be found in the state.

Within the last few years increasing numbers of trickling filters have been installed. The tendency has been to omit final settling tanks, and although this practice is not objectionable where the filter effluent discharges into a stream having a low-water flow sufficient to afford proper dilution, there are many treatment works in Iowa discharging into small creeks that go dry, or nearly so, during the summer months. Furthermore, these streams, in many instances, flow through farm land, and as a result this situation has given rise to complaints below the outlet of several such installations. For this reason this department feels that final settling following trickling filters should be installed in future plants where there is a possibility of insufficient dilution during low flow periods of the stream receiving the filter effluent.

As to the more recent developments in primary treatment, namely, mechanical clarification with separate sludge digestion and the activated sludge process, Iowa has very few such plants. Here again the cause may be attributed to the small size of the towns, the first cost as well as the cost of operation making such plants prohibitory from a financial point of view.

Data obtained by a recent survey of municipalities having sewage treatment works show that of the 920 cities and incorporated towns in Iowa, 319 have sewer systems. On a population basis these 319 municipalities represent 84.5 per cent of the total urban population. Table I gives more detailed information relative to the above figures.

TABLE I

SEWAGE DATA OF IOWA CITIES AND TOWNS

	No.	No. Served by Sewers	Per Cent Served by Sewers	Total Population of Cities in this Class	Total Population of Cities Served by Sewers	Per Cent of Total Population	No. Having Only Primary Treatment	Population of Towns Served	No. Having Primary and Secondary Treatment	Population of Towns Served
First class cities	16	16	100	625,480	625,480	100	..	...	1	22,682
Second class cities	93	92	98.9	360,566	357,750	99.2	6	18,016	43	182,696
Incorporated towns with a population between 1000 and 2000	96	85	88.5	128,316	113,377	88.4	14	19,139	51	67,467
Incorporated towns with a population between 500 and 1000	224	104	46.4	156,889	77,643	49	14	10,581	66	49,666
Incorporated towns with a population less than 500	491	22	4.5	130,411	8,739	6.7	8	3,286	11	4,255
Total of all cities and incorporated towns in Iowa	920	319	34.7	1,401,662	1,182,989	84.5	42	51,022	172	326,706

It is interesting to note that of the 93 second class cities, with populations ranging from 2,000 to 15,000 only one has no sewer system. Also of the 96 incorporated towns with populations between 1000 and 2000, 85 have sewer systems and even in the smaller towns ranging from 500 to 1000 in population, nearly 50 per cent have sewer systems.

It has been previously stated that most of the larger cities have no sewage treatment works. This is further substantiated by the fact that while 66.5 per cent of the municipalities having sewer systems have treatment works, only 31 per cent of the population live in these cities or towns.

Table II shows the types of sewage treatment works in the state.

TABLE II

Primary Sewage Treatment in Iowa

Municipalities Having Separate Sludge Digestion		Municipalities Having Imhoff Tanks		Municipalities Having Septic Tanks		Municipalities Having Septic and Imhoff Tanks	
No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.
3	11,631	81	177,285	124	160,013	6	28,799

Secondary Treatment

Municipalities Having Trickling Filters		Municipalities Having Sand Filters		Municipalities Having Sand and Trickling Filters		Municipalities Having Contact Filters	
No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.
51	138,009	115	162,447	2	9466	4	16,784

Final Treatment

Municipalities Having Final Settling		Municipalities Having Chlorination	
No.	Pop.	No.	Pop.
13	60,351	1	8058

This table indicates that septic tanks for primary treatment outnumber the other and more satisfactory types. There are more than two times as many intermittent sand filter as trickling filters.

The only city using chlorination is so located that the effluent from the final settling tanks discharges into a stream about one mile above a bathing beach. Chlorination is not used in the winter months.

The three separate sludge digestion treatment plants shown have just been recently installed, and Iowa has no activated sludge treatment works.

Table III shows the types of secondary treatment following the different types of primary treatment.

This bears out the statement that trickling filters were not used in this state until recently, since there are more sand filters following Imhoff tanks than trickling filters. Septic tanks were used very little after the advent of the trickling filter. Several of the trickling filters following septic tanks replaced sand filters.

As to the results obtained it may be stated that these are variable, depending upon the operation probably more than the design. Iowa, like all other states, has some plants that are faulty in design, but some of these, if properly operated, give better results than some well-designed plants improperly operated.

TABLE III

SECONDARY SEWAGE TREATMENT IN IOWA

Type of Primary Treatment	Type of Secondary Treatment Following Primary Treatment								Primary Treatment Only	
	Trickling Filters		Sand Filters		Both Sand and Trickling Filters		Contact Filters			
	No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.
Inhoff tank	35	106,804	39	58,395	1	7665	...	...	6	4421
Septic tank	12	15,993	73	90,966	...	..	3	6453	36	46,601
Both septic and Imhoff tanks	1	3581	3	13,086	1	1801	1	10,331	..	...
Separate sludge digestion	3	11,631	...	....	...	..	...	...	..	...
Totals	51	138,009	115	162,447	2	9466	4	16,784	42	51,022

Because most of the plants are located in small towns it is not feasible to employ technically trained operators or even to provide for full-time supervision by anyone. Most of the operators of small plants are employed by the town for other duties and many spend as little time as possible around the sewage treatment works. Another thing affecting the lack of competent supervision is that, due to local politics, the personnel is constantly changing. Thus, the time spent by this department in educating the operators is, in many instances, all but wasted when these changes are made.

All of these factors tend to decrease the efficiency of the entire plant. The results of neglect are probably more quickly noticed in the sand filter than in any other part of the treatment process.

Iowa's experience has been that the sand filter requires more attention and closer supervision than does the trickling filter. Many instances have arisen in which the filter has been neglected for a short time with the result that the only remedy was resanding the entire bed. Sand filters also are more easily thrown out of operation by overloading than are trickling filters. Winter operation has caused more or less trouble throughout the state and many plants by-pass the sand filters during cold weather. Although trickling filters may not produce much better results under the same conditions they do not deteriorate so rapidly as sand filters and are more easily renovated.

Iowa has had very little trouble in the deterioration of filtering material for rock filters. This can be explained by the fact that nearly all rock for trickling filters is quartzite, obtained from South Dakota or Minnesota.

It is needless to say that Imhoff tank treatment is far superior to septic tank treatment, and many of the older septic tanks now giving trouble will be replaced by the Imhoff tank.

During the years 1922, 1923 and 1924 sewage treatment plant construction was at its height. Following this period there was very little work done for the next few years, but within the near future we expect some increase in sewer and sewage disposal plant construction throughout the state.

It is our opinion that much better results could be obtained in operation if this department could make regular inspections of the various treatment works. However, due to the lack of personnel in the engineering division this has been impossible and until adequate state supervision becomes possible, or such a time that the towns see fit to hire technical supervision, the design of plants, particularly for the smaller municipalities, must be such that the operation will be as simple and non-technical as possible.

Sewage Treatment in Wisconsin[1]

BY L. F. WARRICK[2]

Public interest in the treatment and satisfactory disposal of sewage and industrial wastes has been steadily developing in Wisconsin due in large part to an increasing appreciation of the value of clean lakes and streams. Though more adequate protection of the public health is a very important factor in this awakening of public interest, other considerations have stimulated the growing demand that provision be made for reducing objectionable stream pollution to a minimum. Various civic and sportsmen organizations have urged and supported more effective measures of pollution control in order that the waters of the state be conserved for recreational purposes, including fishing, bathing and boating, and that their natural beauty be unimpaired.

Enlargement of the scope of sewage treatment activities to include more adequate supervision over present sewage treatment plants, and to foster construction of new plants where needed to prevent excessive stream pollution, constitute an important part of the program of the Committee on Water Pollution created in 1927 by the Wisconsin legislature. This Committee is composed of the State Chief Engineer, member of the Railroad Commission designated by the Commission, the Conservation Director, or one of his employees whom he may designate to represent the Conservation Commission, the State Health Officer, or a member of the Board of Health designated by the Board, and the State Sanitary Engineer, or other engineer appointed by the State Board of Health. The State Board of Health through the Bureau of Sanitary Engineering is the administrative agency for the Committee.

According to records of the Bureau of Sanitary Engineering, 211 Municipalities have public sewerage systems, 91 of which have provided disposal facilities through 106 sewage treatment plants. In addition there are listed 9 sewerage systems and 3 treatment plants of a semi-public nature. During 1928 a total of 63 plants were inspected by the Bureau, and plans for 34 new, modified or extended sewerage systems were approved.

The present status of sewage treatment in Wisconsin is best shown by reference to the map, Figure 1. Municipalities having sewerage systems with or without treatment plants, are listed at the bottom of the map, and symbols indicate whether the systems are of the combined or separate types and whether partial or complete treatment is provided.

A study of municipal sewerage and sewage treatment systems of the state, grouped on the basis of population, is shown in Table I. This table

[1] *Read at Second Annual Meeting, Central States Sewage Works Association, Indianapolis, Ind., June 20, 1929.*

[2] *State Sanitary Engineer, Wisconsin State Board of Health.*

indicates that developments of new sewerage systems will largely be in municipalities with populations below 2000 on the basis of the 1920 census.

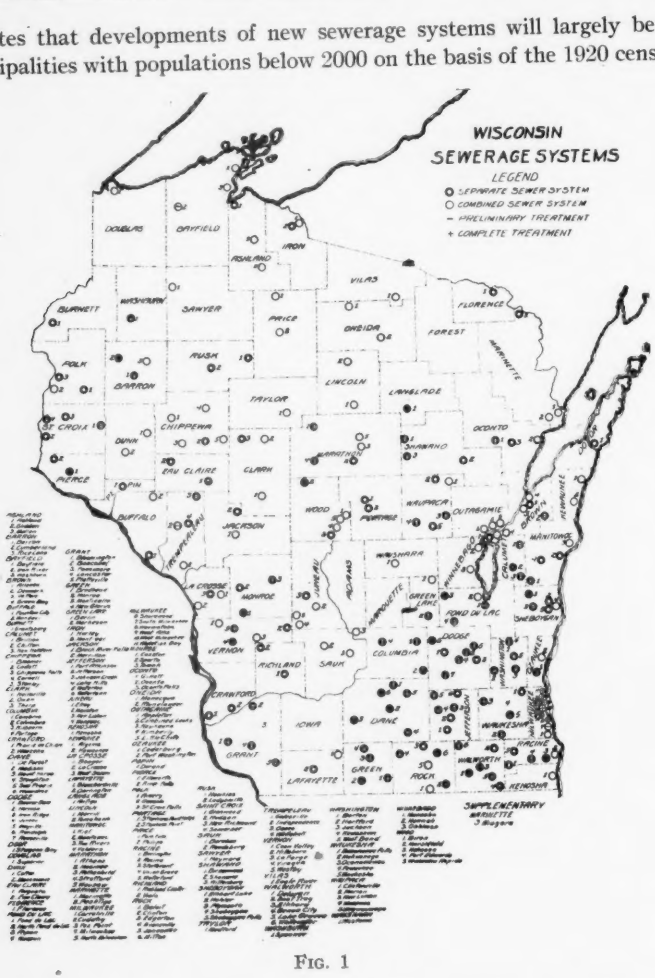


FIG. 1

Many existing systems, however, have been built on the combined rather than the separate plan. Since mixing of the storm water with the domestic sewage complicates and makes more expensive most methods of treatment projects for the construction of new, modified or extended sewerage systems will undoubtedly include a number of the larger municipalities.

Though Table I indicates a relatively low percentage of the larger municipalities as having treatment facilities, approximately 55% of the sewered urban population (1920 census) of the state has been provided with

either partial or complete sewage treatment facilities. The activated sludge plant at Milwaukee is responsible in a considerable part for this high percentage, since it receives sewage from 8 surrounding cities and villages in addition to that from the city of Milwaukee. The majority of treatment plants in other municipalities consist only of some form of tank treatment, though there are in the state some very complete and interesting plants.

TABLE I

MUNICIPAL SEWERAGE AND SEWAGE TREATMENT SYSTEMS IN WISCONSIN GROUPED ACCORDING TO POPULATION

Status of Improvements Jan. 1, 1929	Population Based on 1920 Census												Total No. Municipalities as Classified
	0–499		500–999		1000–1499		1500–1999		2000–2499		2500–Up		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Sewerage only	7	3.5	26	17.7	14	33.4	17	56.7	6	50	50	61.7	120
Sewerage and sewage treatment	7	3.5	25	17.3	13	31.6	9	30.3	6	50	31	38.3	91
No sewerage	178	93	96	65	15	35	4	13	0	0	0	0	293
Totals	192	100	147	100	42	100	30	100	12	100	81	100	504

NOTE.—Tabulation does not include semi-public sewerage and sewage treatment systems.

The tendency in design of sewage treatment plants recently installed has been toward separate sludge digestion as preliminary treatment followed in some cases by trickling or sand filters. Chemical precipitation has been included in a few plants either to produce greater plant efficiency pending development of more complete purification or to assist in securing better clarification where industrial wastes are a factor.

At Hartford and Kiel the sewage is treated in a Dorr clarifier for separation of the suspended solids, which are pumped into another clarifier or thickener where the sludge is digested. These are rather novel plants and have attracted considerable attention throughout the country. Excellent results are being secured in the removal of suspended solids and digestion of the sludge. At New Holstein a Dorr clarifier with lime precipitation has been utilized. This method has been reasonably successful during the canning season when heavy pollution from a pea canning plant must be treated.

An Imhoff tank, trickling filter plant with a capacity of 5 million gallons per day has recently been installed at Madison. Secondary settling and chlorination are provided for the effluent from the filters. At Antigo a new plant has been constructed which consists of a Dorr clarifier and digestor, as at Hartford, with the collection of sewage gas from the digestor for heating of sludge and other purposes about the plant. The effluent from the clarifier is treated on trickling filters. A similar plant is being constructed at Waukesha and will probably be placed in operation during July, 1929.

After sewage treatment plants are installed it appears to be the policy of

many municipalities to foreget about them and pay no attention to maintenance and operation. Any type of sewage treatment requires regular and systematic attention if effective results are to be secured.

Effective sewage treatment depends to a large extent on two primary factors:

1. Provision of adequate funds for operation and maintenance of sewage works, and
2. Suitably trained operating personnel.

The former is mainly a problem for city and village officials, which is frequently forgotten in the preparation of their annual budgets. In some states special funds have been provided for municipal sewage treatment through a small increase in water rates or by a service charge on sewer connections, adjustments being made according to the volume and character of sewage contributed.

Such laws are in effect in Ohio and Michigan. By means of these charges special funds have been created which can be expended only for the operation, maintenance and repair of the sewerage systems and treatment works. According to reports received from city and state officials, very satisfactory results have been secured in the practical application of the Ohio law.

These experiences have been largely responsible for the recent enactment of a sewer rental law in Wisconsin. This law provides as follows:

"SECTION 1. A new subsection is added to section 66.06 of the statutes to read: (66.06) (22) (*a*) Any town, village or city which shall have installed or shall install, pursuant to the approval of the State Board of Health, a plant for the treatment or disposal of sewage may establish and collect from the respective owners of the property which is served directly or indirectly by said plant reasonable rental charges, and, for the purpose of making such rental charges equitable, may classify the property benefited thereby, taking into consideration the volume and character of the sewage or waste and the nature of the use made of such sewerage facilities. Said rental charges shall be collected or taxed against the property in like manner as water rates are collected and taxed under the provisions of paragraphs (*a*) and (*b*) of subsection (11) of section 66.06. The income derived from such rentals shall be kept in a special trust fund by the municipal treasurer subject only to disbursement by order of the municipal council for the operation, maintenance and repair of the municipal sewerage system and sewage treatment works.

(*b*) Any twenty-five or more freeholders of such a municipality may file complaint with the railroad commission to the effect that the rental charges so fixed are unreasonable or unjustly discriminatory, and the railroad commission shall, after public hearing thereon, file its findings and determination stating therein in what respect, if any, said rental charges are unreasonable or unjustly discriminatory, and the municipality at interest shall forth-

with readjust its rental charges so as to remove any unreasonable or unjustly discriminatory features so found by the railroad commission. Any party in interest may appeal from the findings and determination of the railroad commission in like manner as provided in sections 196.41 to 196.48."

Already interest in this law has been shown by several Wisconsin municipalities and it is anticipated that advantage of the law will be taken by some cities and villages in making adequate financial provision to secure effective sewage treatment.

To assist in the improvement of sewage treatment conditions in Wisconsin, the State Board of Health has adopted a program of annual plant inspections and coöperative studies with the operators and municipal officials. Sewage treatment is not an empirical matter which can be successfully accomplished by any set formula or "rule of thumb" method. It is a matter which presents numerous problems, a great many of which have not yet been satisfactorily explained. There are, however, certain underlying or basic principles which apply to all methods of sewage treatment and should be understood by a plant operator in order that he may intelligently cope with some of the common difficulties encountered with sewage plants. A lack of knowledge of these fundamentals has frequently resulted in the partial or complete failure of treatment works representing a considerable public investment.

Though substantial progress has been made to obtain effective sewage treatment in Wisconsin, there is much yet to be accomplished both from the points of view of securing new treatment works and more efficient operation of existing plants. It is believed, however, that with awakened public interest in clean lakes and streams, and with a coöperative program of activities to promote greater operation efficiency, the next few years will show many improvements in the status of sewage treatment in Wisconsin.

Sewage Treatment in Michigan[1]

BY W. F. SHEPHARD[2]

In order to understand fully the status of sewage treatment in the state of Michigan it is necessary to know something of the nature of the state from a geographical standpoint.

Michigan is divided into two main sections designated locally as the Upper and Lower Peninsula. The Upper Peninsula is somewhat sparsely settled, being largely devoted to mining and lumbering industries. The four largest cities are Ironwood, Marquette, Sault Ste. Marie and Escanaba, each of which has a population between 15,000 and 20,000. All of these except Ironwood are located on the shores of the Great Lakes or connecting streams. The Lower Peninsula can be roughly divided into three sections, one being that north of an east and west line through Bay City, another composed of Wayne, Oakland and Macomb Counties, which essentially is a Detroit metropolitan area, and the rest of the Lower Peninsula. These counties are essentially agricultural in character, although there are some industrial areas such as at Flint, Muskegon, Lansing, Kalamazoo, Jackson and a few others of similar characteristics. The northern counties are sparsely settled and have no cities with a population much in excess of 10,000 and only three or four approaching this size. With one exception these cities are located on the Great Lakes. The area about Detroit is of course densely inhabited, supporting a population of perhaps 1,500,000. The land of this district is generally very flat and only a few feet above the Detroit River.

An indication of the relative urban population and stream flows in the state is given in Table I. The minimum stream flow is taken as the minimum, two or three months for which there is available information. These figures are in many instances not much more than estimates but are the best records available. In several drainage basins a great percentage of the urban population is concentrated in one city at the mouth of the stream where part of the sewage is discharged into the lake and consequently may indicate something of a higher loading than actually exists. This is particularly true in the Muskegon, Manistee, Boardman and Thunder Bay drainage basins where over 97 per cent of the urban population is concentrated in a community at the mouth of the stream. The urban population given is the estimated 1926 population of incorporated cities or villages having populations in excess of 2500. In considering this table it should further be remembered that in many instances this population is divided between communities several miles apart and also that the

[1] *Read at Second Annual Meeting, Central States Sewage Works Association, Indianapolis, Ind., June 20, 1929.*

[2] *Asst. Sanitary Eng., Michigan State Dept. of Health.*

stream flow given is the discharge at the mouth of the stream and may be materially different at any given city. It does, however, give something of a picture of the problem of sewage treatment in Michigan so far as the dilution factor is concerned.

TABLE I

URBAN POPULATION, DRAINAGE AREAS AND MINIMUM MONTHLY DISCHARGE OF MAJOR STREAMS

River	Urban Population	Drainage Area in Sq. Miles	Est. Min. Runoff Cu. Ft. per Sec.	Cu. Ft. per Sec. per 1000 Pop.
St. Joseph	45,286	4586	1000	22.2
Kalamazoo	118,685	2064	1100	9.3
Grand	330,685	5572	900	2.7
Muskegon	62,215	2663	750+	12.0
Little Manistee	9,694	267	...	...
Manistee	10,646	2018	1000±	94.0
Boardman	10,925	304	300±	27.5
Thunder Bay	11,101	1267	300	27.2
Tittabawassee (incl. Saginaw)	99,282	2500	500	5.1
Shiawasee	23,362	2500	400±	17.3
Flint	135,546	1394	75	0.55
Cass	2,984	1013	35	11.6
Clinton	83,436	677	120	1.45
Rouge (incl. 100,000 of Detroit)	145,000	400±	40	0.27
Huron	30,228	1043	100	3.3
Raisin	29,232	1129	100	3.4

In many instances the use of surface water for a domestic water supply makes sewage treatment a necessity. This is particularly true of those communities around the lake shores. There are in Michigan 331 public water supplies. Of these about one-third (112) are surface supplies. Fifty-two of these supplies are protected by chlorination only and an additional 27 are filtered. An additional 21 supplies are not supposed to be used for domestic purposes, being essentially fire protection supplies, mostly in small places.

Legal Control

Responsibility for the enforcement of laws relative to sewage treatment and stream pollution rests with the State Departments of Health and Conservation. The Commissioner of Health is required to examine and approve plans for sewerage and water systems and to order such changes as he deems necessary. Various acts have been passed requiring the State Department of Conservation to enforce laws regarding stream pollution. Recently an act was passed whereby sewerage systems and sewage treatment plants can be put upon a utility basis and charges made to the consumer similar to any other public utility. It further authorizes the issuance of bonds without a popular vote upon order from a court of competent jurisdiction. An amendment to the drainage laws of the state make it

possible for treatment plants to be built and maintained by the County Drain Commissioner under certain conditions. The last Legislature has passed a bill following a constitutional amendment, whereby metropolitan districts may be formed for various phases of public activities.

Health Department Supervision of Operation

The Bureau of Engineering of the State Department of Health maintains supervision over the operation of sewage treatment plants. To maintain as close contact as possible with the plants, monthly reports are filed with the department by the operators on blanks provided for that purpose. It has been found desirable to use two forms for this purpose. One is a brief form on an $8^1/_2 \times 11$ sheet and is intended to supply only such fundamental information as the "Street Superintendent-Town Marshal" type of operator can get. Quantity of sewage flow, settling solids tests, relative stability, depth of sludge, date and amounts of sludge drawings are the more important items. A few fundamental instructions are printed on the back of the blank.

A second type of blank is used for the larger plants where more elaborate supervision is available. Space is provided for recording complete chemical analyses, including total and suspended solids, organic solids, pH, residual chlorine, bacteria count and similar information. It seems quite difficult to perfect a report sheet which will satisfy all conditions and this was prepared after considerable investigation of blanks used in other states.

In addition to the information obtainable from these reports an assistant engineer is detailed to supervise the operation of these plants. It is possible for him to visit each plant from two to four times a year. No routine schedule is followed in making these visits, since it seems advisable to visit the plants where difficulty is being encountered more often than others.

By way of attempting to increase the operator's technical knowledge and operating skill and to improve the operation of the plants an annual meeting is held at Lansing. These meetings have been held for four successive years. At the third meeting, an organization was perfected, officers chosen and the control of the meetings placed in the hands of the operators.

Number and Type of Plants

As may be expected from the discussion of the physical conditions in Michigan, there are not many treatment plants in Michigan. At present there are 36 municipal plants of sufficient size and capacity to be considered workable, and 11 plants serving state, county and private institutions. Some of the institutional plants are of a size comparable with small municipal plants, treating as they do over a quarter of a million gallons per day. Types of plants embrace almost the entire category of sewage treatment works. Septic tanks, plain sedimentation tanks, Imhoff tanks, intermit-

tent sand, contact and sprinkling filters, chemical precipitation, chlorinating plants and activated sludge are included. Additional plants either under construction or advertised for bids will include sedimentation tanks using mechanical sludge removal equipment, some with sludge digester mechanisms, one with aeration following preliminary sedimentation and three with gas collection and heating of sludge. To date there are no covered sludge beds in Michigan.

Table II is a list of types of plants and the numbers of each type in service in Michigan.

TABLE II

Septic tank	17	Sand filters	19
Chemical precipitation	1	Contact filters	5
Imhoff	23	Trickling filters	4
Separate sedimentation	5	Activated sludge	1
Broad irrigation	2	Chlorination	2

In addition there are now under construction or advertised for bids one sedimentation and aeration plant and three separate sedimentation plants, one of which will chlorinate the effluent from the settling tank.

Pontiac and Flint Plants

There are in Michigan two plants of somewhat unusual types which may be of interest. These are located at Pontiac and Flint.

Pontiac is an industrial town of some 60,000 people located about 30 miles northwest of Detroit. It is just inside the Clinton River Drainage Basin and discharges the effluent from its treatment plant into the Clinton River. The minimum monthly flow of the river at this point probably does not exceed 30 cu. ft. per second. Prior to 1920, riparian owners below the city, which had then a population of about 35,000, filed suit against the city asking damages and abatement of a nuisance created by the discharge of untreated sewage into the stream. The court ruled in favor of the plaintiffs and a treatment plant was constructed. The city is sewered on the separate system but a large amount of storm water finds its way into the sanitary sewer system. During times of heavy storms the rate of flow becomes as much as ten times the average. Normally the sewage is a highly concentrated domestic sewage with some packing house wastes.

The plant consists of a battery of four longitudinal-flow Imhoff tanks, sludge drying beds, eight trickling filter units and three secondary tanks. The tanks each have three flowing-through chambers 9 feet wide and 98 feet long. The depth of water to the slots is 12 feet. Each tank has two gas vents running nearly the full length of the tank. Four sludge hoppers are provided in each unit, each equipped with sludge pipe. Total water depth is 28 feet 6 inches. The sludge storage capacity of each unit is

about 22,000 cubic feet. Sludge is drawn by gravity to one drying bed and pumped to another.

The filters are the unique part of this plant. They are circular in plan with a diameter of 110 feet. Sewage is applied by means of a revolving distributor which operates with the available hydrostatic head.

The total difference in elevation between the water surface of the Imhoff tanks and the surface of the stone is 2 feet 8 inches. With this small loss of head it was possible to treat the sewage without pumping with a consequent economy in operation. The depth of stone used is somewhat less than the usual amount, being about 5 feet 6 inches. Three secondary tanks are provided. These are circular in plan and of the radial flow type. Sludge is removed by pumping.

It seems to be the general opinion that filters of this type cannot be operated in climates similar to those of the northern United States. This has not been the case at Pontiac. These filters have operated through seven or eight Michigan winters, where zero temperatures are not at all unusual, and have given no trouble. A ring of ice will sometimes form around the outside wall. The operator readily overcomes this difficulty by opening shear gates at the ends of the arms for a few minutes. The increased flow melts the ice ring sufficiently to prevent trouble. This is necessary only under exceptional circumstances. In fact the net area of filter under ice is a materially less percentage with this type than with the fixed-nozzle type operating at Plymouth, about thirty miles away. In the eight years of operation of this plant the only repairs to the filter mechanism were the replacement of some bearings. Probably the entire repair bill did not exceed $250, including labor. In operation these distributors are relatively easy to keep clean. When the holes in the arms become stopped up a hose stream is found very effective in cleaning them. The entire eight units can be cleaned in about two hours.

For the past four years the plant has been heavily overloaded due to the unprecedented growth of the city. At present some eight m. g. d. is received at the plant for which four m. g. d. is a normal load. Probably because of this excess loading the Imhoff tanks have given considerable trouble by foaming. Last year a chemist was employed to assist the operator and a real attempt was made to discover the true conditions at the plant. From such computations as he could make it was brought out that the digestion tank provides less than thirty days storage capacity. The pH of the sludge ran about 6.8. By addition of lime and removal of sludge as rapidly as possible the troubles have been greatly minimized. During the first five months of 1929 about 9000 cu. yd. of wet sludge has been removed from the tanks, and the sludge level is now within three feet of the slots. The character of sludge produced is quite surprising considering the limited digestion, since it has not produced particularly bad odors as yet.

At the end of the season last year all the dried sludge from the plant had been disposed of. Most of this was sold to golf courses for fertilizer, although considerable had been used for lawns at a county hospital which had just been erected. Disposing of the digested sludge seems no longer to be a problem of consequence at this plant.

The treatment works at Flint, Michigan, were put in operation in October, 1927. At present they consist of Imhoff tanks and appurtenances, with secondary treatment to be installed in the near future. The plant treats an average daily flow of 10 m. g. d. from an estimated connected population of 120,000. The sewerage system is of the separate type and is fairly free from storm water. The tanks are the unusual feature of this plant. There are four units each with a rated capacity of 4 m. g. d. with a nominal detention period of four hours. Sludge digestion capacity is provided on the basis of 2.75 cubic feet per capita for a population of 40,000. Sewage enters through a vertical riser pipe in the center of the unit to an inlet chamber which is at the center of a hexagon unit. It then flows radially outward to a series of collecting weirs arranged around the periphery of the unit. The digestion chamber is divided into hexagonal cells, six being in an inner ring and twelve dovetailing into an outer ring around this, using common walls where possible. Each cell is provided with a hopper and sludge pipe. Common walls between cells have large openings to provide intercommunication. Sludge slopes forming the bottoms of the sedimentation chambers are precast and so placed as to form a gas vent over each sludge chamber cell, in a manner similar to an ordinary radial flow unit. Suitable connecting walkways are provided to afford access to the tanks at all points. Maximum depth of water is about 35 feet. The total cost of the plant itself exclusive of land, pumping station and force mains was $542,000 or $3.39 per capita.

The advantages of the design appear to lie in the extremely low velocity obtained in the sedimentation chamber with resultant efficient sedimentation, economy in construction, and obviating the necessity for reversal of flow such as is ordinarily required.

Operating results have been quite satisfactory. An average removal of suspended solids of 68.7 per cent has been attained. For several months nearly 80 per cent was attained. Some difficulty was encountered with foaming. To remedy this the tanks were nearly emptied of the first winter's sludge accumulation. Since then circulation of sludge has proven beneficial. The difficulties have not been entirely surmounted but good results are being obtained. Very good records are kept and the plant is well operated.

Editorial

Regional Problems

Although the fundamental facts of the science of sewage treatment may have universal application, specific regional conditions throughout our country permit modifications and novel applications of standard practices. The discussions in this issue of the status of sewage treatment in California, Iowa, Michigan and Wisconsin illustrate this fact.

California's sewage problems are almost as diversified as its climate. For the state as a whole it is probable that ocean dispersion typifies the most common means of sewage disposal. The mild, equable climate of Southern California permits sludge drying throughout most of the year. Here there are no problems of stream pollution under winter ice sheets, as in Wisconsin and Michigan. On the other hand the summer nuisance problems of mid-western streams are sometimes prolonged in this sunny climate. High temperature, long outfall sewers and sulphate-bearing sewages have created unique problems of sewer disintegration. The importance of water conservation exacts consideration of complete treatment of sewage for recovery of the liquid itself. Industrial wastes, mainly from canning factories, oil refineries and steel-pickling plants are of increasing importance.

The sandy soil of Iowa suggested the use of intermittent sand filtration while its cities were small and industrial wastes were absent. Now the growth of cities and the presence of industrial wastes require more intensive and more easily controllable processes of sewage treatment. The story of the struggle with industrial wastes at Mason City is almost as epochal as the 40-year struggle with industrial wastes at Worcester, Massachusetts. Iowa is rich in knowledge of what should be done to improve the status of sewage treatment because of its colleges, universities and experiment stations, but the state as yet contains but few modern treatment plants.

Wisconsin is making rapid progress in the installation of sewage treatment works. The state-wide problems are mainly due to industrial wastes from dairies, paper mills and vegetable canneries. The State Department of Health has conducted interesting and important studies of the treatment of these wastes, alone and mixed with sewage. The pollution of streams is not a matter of superficial concern in Wisconsin, for there the Izaak Waltonian still has fishing streams and nature undefiled; but a paper mill will quickly ruin a good trout stream.

Michigan's sewage problems are closely akin to those of Wisconsin. The two treatment plants described particularly by Mr. Shephard (Pontiac and Flint) are probably unique in this country.

A review of the major problems of sewage disposal in these four states demonstrates that although regional problems vary according to climate and topography, the question of disposal of industrial wastes is always present. The ubiquity of this problem is of concern to the consulting engineer, to the treatment works operator and to the public at large. We know woefully little about industrial wastes. Further knowledge is of the utmost importance for the successful development of modern sewage treatment and stream purification.

Ferric Salts as Coagulants

A striking feature of the short history of scientific sewage treatment is the recurrence of ideas, at one time thought worthless, but in the light of further knowledge found to be of practical value and application. Such re-application of wellworn principles may develop from studies of coagulants for various phases of sewage treatment.

The use of lime, alumino-ferric and other mixed coagulants for precipitation of sewage is still common practice in England but in America there are no modern plants using these chemicals. This does not mean that coagulants are obsolete. The interesting work of Dr. Rudolfs opens up a wide field for research on the use of ferric salts. The revival of interest in ferric chloride may be ascribed to the work of Palmer at the Calumet Treatment Works. His study of the remarkable coagulative properties of ferric chloride on activated sludge led to the large-scale use at Milwaukee. Anyone who has seen the large flocs produced by ferric chloride has a visual conception of its efficiency. The cost of ferric chloride four years ago was prohibitive, and consequently chlorinated ferrous sulphate was made in order to obtain a ferric coagulant at a reasonable cost. But this coagulant was found to be inferior to the more expensive ferric chloride. In view of the pressing need for the better coagulant at Milwaukee, and after painstaking experimental work, it was found that the cost of producing ferric chloride could be greatly reduced, in fact to about one-third of the original amount, by utilization of chlorine and iron at the electrolytic chlorine plants.

This newly-produced coagulant may have possibilities. The use of very small amounts in Dr. Rudolf's experiments produced marked coagulation of sewage colloids and resulted in increased removal of suspended solids. There may be uses for the salt in accelerating the drying of sludge; in reducing odors; in coagulation of water; in improving the rate of settling

of activated sludge; and in the clarification of industrial wastes not amenable to other coagulants. In short, an interesting field of research is revealed.

This development only proves a basic truism of sewage research: Presumably obsolete processes and practices of sewage treatment may be revived under more modern conditions and may develop into practical, usable adjuncts of sewage treatment.

Mechanical Sludge Removal

The manual removal of sludge from sand beds is no longer in keeping with the developments of this mechanical age. Although cleaning by hand may be cheaper for small plants, mechanical devices are absolutely essential for the satisfactory and economical operation of large treatment works on the tremendous scale of such plants as the West Side Treatment Works of the Sanitary District of Chicago, which is to include fifty-seven acres of sludge beds and a standard gage railroad and rolling stock for the disposal of dried sludge.

This necessity is the mother of the invention of the mechanical cleaner now in use at the Calumet Treatment Works, described on page 448 of this issue. A mechanical device of somewhat different type is in use in Stuttgart, Germany. Sohler's cost estimates for this cleaner are given on page 510. A machine of somewhat different design is in use in Munich (THIS JOURNAL, Vol. I, p. 229, Jan., 1929). A Barber-Greene loader has been used at Worcester, Massachusetts, for several years.

These developments indicate that there will soon be available several types of mechanical cleaners which will be superior to hand-cleaning from the standpoints of cost, convenience, and freedom from loss of sand.

Proceedings of Local Associations

New York State Sewage Works Association
First Annual Meeting

Albany, New York

May 4, 1929

The First Annual Meeting of the New York State Sewage Works Association was held May 4, 1929, in Albany. There were 23 persons in attendance and a total of 83 have applied for membership.

The constitution and by-laws were drawn up and adopted and officers for the ensuing year were elected. It was voted to apply for membership in the Federation and accordingly a copy of the constitution and formal application were sent to Mr. H. W. Streeter, Chairman of the Membership Committee of the Federation.

The officers elected were as follows:

President: Kenneth Allen, 2700 Municipal Building, New York City.

Vice-President: C. A. Holmquist, State Department of Health, Albany, N. Y.

Secretary-Treasurer: E. S. Bedell, State Department of Health, Albany, N. Y.

Executive Committee: Term of 1 year—Kenneth Allen, R. H. Gould, R. Suter. Term of 2 years—H. B. Cleveland, M. M. Cohn, Glenn D. Holmes. Term of 3 years—Earl Devendorf, C. A. Holmquist, John F. Skinner.

Representatives on Board of Control, Federation of Sewage Works Associations: Term of 1 year—Kenneth Allen. Term of 2 years—C. A. Holmquist.

It is planned to hold an "inspection" meeting in Rochester, N. Y., July 27, 1929, at which time a luncheon will be held and inspection trips planned.

A "conference" meeting will probably be held at Albany in October.

The constitution was adopted as follows:

New York State Sewage Works Association Constitution

ARTICLE I

NAME

The name of this organization shall be the New York State Sewage Works Association, hereinafter designated as the Association.

ARTICLE II

OBJECTS

The objects of this Association shall be:

SECTION 1. The advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of works for the collection and treatment of these wastes.

SECTION 2. The promotion and encouragement of improved waterways sanitation, through the same measures.

SECTION 3. The encouragement of a friendly exchange of information and experience among its members, and other interested persons, by an annual convention of its members, the publication of proceedings of its meetings, affiliation with the Federation of Sewage Works Associations, and participation in the activities of that organization.

ARTICLE III

MEMBERSHIP

SECTION 1. A member of this Association may be either an Active Member, an Associate Member, or a Contributing Member.

SECTION 2. An Active Member shall be a person connected with the administration, supervision or operation of one or more sewerage or sewage disposal works; a civil, sanitary, hydraulic, mechanical or electrical engineer; a chemist or a bacteriologist, or any qualified person engaged in the advancement of knowledge relating to sewerage or sewage disposal, or a municipality of the State of New York.

A municipality becoming an Active Member shall be entitled to but a single vote.

Active Members joining the Association before July 1, 1929, shall be designated as Charter Members.

SECTION 3. An Associate Member shall be a person, firm or corporation engaged in the manufacture or sale of materials, equipment or supplies for the construction or maintenance of sewerage or sewage disposal works. An Associate Member may be represented by one person at each meeting. Neither Associate Members nor their representatives shall be entitled to vote in the business meetings of the Association.

SECTION 4. Any member contributing fifty dollars or more in addition to the regular dues shall be designated as a Contributing Member for the fiscal year in which payment is made.

ARTICLE IV

ORGANIZATION

SECTION 1. The government of the Association shall be vested in an Executive Committee of nine Active Members, subject to the conditions of this Constitution and By-Laws, three to be elected by letter ballot annually to serve for three years, except that the first Executive Committee shall consist of three Active Members serving for one year, three serving for two years and three serving for three years. Their term of office shall begin at the close of the Annual Meeting.

SECTION 2. The officers of the Association shall consist of a President, a Vice-President, and a Secretary-Treasurer. The President and Vice-President shall be chosen by the Executive Committee from among their members, and these officers shall also serve as Chairman and Vice-Chairman, respectively, of the Executive Committee. Neither Members of the Executive Committee, the President, nor the Vice-President shall be eligible for two consecutive terms of office. The Secretary-Treasurer shall be

appointed from among the membership of the Association, but he shall not be a member of the Executive Committee.

SECTION 3. Five members of the Executive Committee shall constitute a quorum for the transaction of business.

SECTION 4. A Nominating Committee shall be appointed by the Executive Committee not less than 60 days prior to the date set for the next Annual Meeting.

SECTION 5. Not less than 30 days before the next Annual Meeting the Nominating Committee shall nominate candidates for membership in the Executive Committee for the ensuing year and present their names to the Secretary of the Association.

SECTION 6. The Secretary shall prepare and send to each Active Member an official letter ballot not less than 20 days before the next Annual Meeting with two envelopes: one addressed to the Secretary and one blank. Only those ballots received by the Secretary before 9 a.m. of the day of the Annual Meeting shall be counted.

SECTION 7. The vote shall be canvassed at the Annual Meeting by tellers appointed by the President and the result reported to the Annual Meeting.

ARTICLE V

AMENDMENTS

SECTION 1. Proposed amendments to the Constitution shall be signed by at least 5 Active Members and submitted in writing to the Executive Committee at least 60 days before the Annual Meeting of the Association, and the said Committee shall submit them by letter ballot to the Active Members at least 30 days before the annual meeting. A two-thirds vote of the ballots cast in the affirmative shall result in the adoption of an amendment, except that

SECTION 4*a*. At the First Meeting of the Association the Nominating Committee shall be chosen by the members present.

SECTION 5*a*. At the First Meeting of the Association the Nominating Committee shall present nominations to the Temporary Secretary before the end of the meeting.

SECTION 6*a*. At the First Meeting of the Association the election of the Executive Committee shall be by ballots distributed to those present.

SECTION 7*a*. The votes of the first Executive Committee of the Association shall be canvassed at the First Meeting by tellers appointed by the Temporary Chairman and the result reported at the meeting.

BY-LAWS

ARTICLE I

ADMISSION

SECTION 1. Any person or organization, municipal or otherwise, desiring to become a member of the Association shall make application for membership on the blank form provided by the Association. Applications shall be forwarded to the Secretary, who shall submit them to the Executive Committee.

SECTION 2. An affirmative vote of five of the Executive Committee shall be required for election of an applicant as member.

SECTION 3. No member whose dues are in arrears shall receive the publications of the Association until such dues are paid. Members in arrears for one year shall be dropped from the roll by the Secretary.

SECTION 4. Any member who has been suspended for non-payment of dues may be reinstated by a majority affirmative vote of the Executive Committee, upon payment of all back dues.

SECTION 5. Any member may be expelled from the Association for non-payment of dues or other cause by a majority vote of the Executive Committee.

ARTICLE II

FEES AND DUES

SECTION 1. There shall be no admission fee for Active Members. The annual dues of Active Members shall be three dollars.

SECTION 2. Associate Members shall pay an admission fee of ten dollars.

SECTION 3. Associate Members shall pay annual dues of ten dollars.

SECTION 4. Annual dues shall be payable in advance and shall be due on January 1st, the first day of the fiscal year covered by said dues.

SECTION 5. One dollar from the annual dues of each member shall be paid to the Federation of Sewage Works Associations and entitle each member in good standing to full membership in said Federation and all perquisites attached thereto.

ARTICLE III

DUTIES OF OFFICERS

SECTION 1. The President shall preside at all meetings of the Association and as Chairman of the Executive Committee at which he may be present.

SECTION 2. The Secretary-Treasurer shall, subject to the Direction of the Executive Committee, be the active business agent of the Association and as such shall receive all dues, subscriptions and other monies paid to the Association. He shall pay bills against the Association and make a report of all receipts, expenditures and debts of the Association at the Annual Meeting. He shall also act as recorder of the Association and keep a complete record of its transactions.

SECTION 3. The Executive Committee shall at all times act in the capacity of director and shall supervise and control the affairs of the Association. It shall hold at least one meeting during the session of each annual meeting.

ARTICLE IV

COMMITTEES

SECTION 1. There shall be a Publication Committee, a Membership Committee and such standing or special committees as may be created, the members of which shall be appointed annually by the Executive Committee.

SECTION 2. The Publication Committee shall consist of three Active Members. It shall pass upon and edit all papers presented to the Association, and, if they are deemed of sufficient importance, transmit them to the Editor of the SEWAGE WORKS JOURNAL for publication.

SECTION 3. The Membership Committee shall be of a size to be decided by the Executive Committee, of which not over 20 per cent may be Associate Members. Its duty shall be to secure desirable members for the Association.

ARTICLE V

MEETINGS

SECTION 1. A regular Annual Meeting of the Association shall be held at such place and on such date as shall be selected by the Executive Committee.

SECTION 2. Special meetings may be held at such times and places as designated by the Executive Committee.

SECTION 3. Notices of all meetings shall be sent out by the Secretary at least thirty days in advance.

ARTICLE VI

AMENDMENTS

SECTION 1. Proposed amendments to the By-Laws shall be signed by at least five Active Members and submitted in writing to the Executive Committee at least three

days before the Annual Meeting and the Committee shall present them at the Annual Meeting for action.

SECTION 2. An affirmative vote of two-thirds of the Active Members present at said meeting shall be required for adoption.

New England Sewage Works Association
First Annual Meeting

Hotel Bond, Hartford, Conn.

April 23, 1929

The First Annual Meeting of the New England Sewage Works Association was held April 23, 1929, at the Hotel Bond in Hartford, Connecticut, in conjunction with the New England Health Institute.

The constitution of the Association was adopted at that time and is as follows:

Constitution of The New England Sewage Works Association

ARTICLE I

The name of this Association shall be the New England Sewage Works Association, covering the States of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut.

ARTICLE II

The object of this Association shall be the advancement of the knowledge of design, construction, operation, and management of sewage works and the encouragement of a friendly exchange of information and experience.

ARTICLE III

Membership shall be of one kind only, to be known as a member. Any superintendent, manager, or other officer of a municipal or private sewage works, a civil, hydraulic, or sanitary engineer, chemist or bacteriologist, or any Board, Commission or Department, or any person engaged in the design, construction, operation or supervision of sewage equipment, may be a member of the Association.

Any Board, Commission, Department, Municipal or private corporation, shall have one vote only at the meetings of this Association.

ARTICLE IV

Any person, Board, Commission, Department, Municipal or private corporation desiring to become a member of this Association, shall make a written request for admission to the Secretary. A majority vote of the membership committee shall be necessary for election to the Association.

ARTICLE V

The annual dues shall be two dollars ($2.00), payable in advance, one dollar ($1.00) of which shall constitute a subscription to THE SEWAGE WORKS JOURNAL, or other publication. The fiscal year shall begin January 1 and end December 31.

ARTICLE VI

The officers of this Association shall be: a President, two Vice-Presidents, a Secretary and a Treasurer. The term of office shall be for one year. No officer, except the Secretary, may hold office for more than two consecutive years.

ARTICLE VII

The President, Vice-Presidents, Secretary and Treasurer shall constitute the Executive Committee to carry on the work of the Association between annual meetings.

ARTICLE VIII

The annual meeting shall be held in the month of April, at such time and place as a majority of the Executive Committee shall appoint. Special meetings shall be held at such times and places as arranged by a committee on special meetings, appointed by the President. Thirty days' notice of such meetings shall be given by mail to all members.

ARTICLE IX

There shall be a membership committee consisting of the President, Secretary, and one member of the Association appointed by the President, which shall examine the qualifications of and vote upon, the admission of all applications and report its action to the Association.

ARTICLE X

The officers are hereby authorized to join this Association with other Associations constituted for like purposes in forming a Federation Board for the publication of a JOURNAL OF THE FEDERATION OF SEWAGE WORKS ASSOCIATIONS. For this purpose they are empowered (1) to appoint a representative or representatives on said Federation Board, in accordance with its articles of organization and (2) to pay to said Federation Board the entrance fee and the annual fee required per capita as collected from each member of this Association for the publication, as in accordance with the said articles of the Association, but not to exceed one dollar ($1.00) annually. If said requirements are carried out, each member of this Association in good standing, shall receive a copy of the publication issued by the Board.

ARTICLE XI

The officers of this Association shall not incur any liability on behalf of the Association in the excess of the amount actually in the Treasury collected from dues from the members.

ARTICLE XII

Upon petition of ten or more members to, or on the motion of the Executive Committee, amendments to the Constitution may be made by a two-thirds vote of the members present at the annual meeting, at least thirty days' notice being given of the proposed amendment in the call for the meeting.

The officers elected at this meeting were:

President: Stuart E. Coburn, Metcalf & Eddy, Statler Bldg., Boston, Mass.

Vice-Presidents: J. W. Bugbee, City Laboratories, Field Point, Providence, R. I.; Warren J. Scott, State Department of Health, 8 Washington St., Hartford, Conn.

Treasurer: Roscoe H. Suttie, Dept. of Civil Engineering, Yale University, New Haven, Conn.

Secretary: F. W. Gilcreas, Weston & Sampson, 14 Beacon St., Boston, Mass.

The delegates elected to the Board of Control of the National Federation were: Stephen De M. Gage, 327 State Office Bldg., Providence, R. I.; Gordon M. Fair, Harvard Engineering School, Harvard University, Cambridge, Mass.

The morning session of the meeting was presided over by Edward Wright, assistant engineer of the Massachusetts State Department of Health. The papers presented dealt entirely with the engineering aspects of sewage treatment and were as follows: "Some Newer Aspects of Sludge Digestion Problems," by Prof. Gordon M. Fair, Harvard University; "Design and Operation of Sewage Tanks," by C. A. Emerson, Jr., Philadelphia, Pa.; "Difficulties with Sewage Plant Operation," by J. R. Downes, Plainfield, N. J.

Mr. Stephen De M. Gage was chairman of the afternoon session, at which time a discussion of the formation of a New England Sewage Works Association was opened by Stuart E. Coburn of Boston, Mass.

A paper on "The Activated Sludge Method of Sewage Disposal" was presented by W. R. Copeland of Hartford, Conn.

A discussion on the "Value of Keeping Sewage Plant Records" was opened by J. Frederick Jackson of New Haven, Conn.

A round-table discussion of filter-plant operation led by Roy S. Lanphear of Worcester, Mass., closed the First Annual Meeting of this new association.

Central States Sewage Works Association
Second Annual Meeting
Indianapolis, Indiana

June 20–21, 1929

The Second Annual Meeting of the Central States Sewage Works Association was held June 20 and 21, 1929, at the Spink Arms Hotel in Indianapolis. The total attendance of registered members was fifty-five.

The meeting was called to order Thursday, June 20th, at 10:00 a.m. by Mr. Robert Cramer, President of the Association. Mr. Cramer introduced Mr. Lewis Finch, Chief Engineer of the Indiana State Department of Health, who delivered the address of welcome in the absence of Mr. Hurd. Mr. Cramer then gave the presidential address in which he spoke on the work of the Association, and for the help he received from Mr. Finch, vice-president, Mr. Radebaugh, secretary, Mr. Warrick, treasurer, Mr. Hansen,

program committee, and Dr. Mohlman, publicity. He spoke in gratitude for the Federation *Journal* and the financial support from the Chemical Foundation for its publication. He said that the "art of sewage disposal was held back by lack of knowledge of operation and lack of appreciation on the part of the public" and that these limitations could be minimized by the local association meetings and publications.

The program for the morning consisted of papers presented on the present status of sewage treatment in the following states:

Indiana, by Mr. Lewis S. Finch, Chief Engineer of the State Dept. of Health.

Wisconsin, by Mr. Louis Warrick, State Sanitary Engineer.

Michigan, by Mr. W. F. Shephard, Asst. Sanitary Engineer of the State Dept. of Health.

Illinois, by Mr. H. F. Ferguson, Chief Sanitary Engineer of the State Department of Health.

Iowa, by Mr. W. W. Towne, Asst. Engineer of the State Dept. of Health.

The papers by Messrs. Warrick, Shephard and Towne are published in this issue of THE JOURNAL.

The morning papers were followed by a description of the sewage treatment works in Indianapolis by Mr. Charles Hurd, Chief Engineer of the Indianapolis Sanitary District, and the operating features of the plant were described by Mr. C. K. Calvert.

A luncheon meeting was held from 12:30 to 2:30 at which time Dr. W. F. King, State Commissioner of Health of Indiana, addressed the group and discussed the matter of cross-connections in water supply systems. His address was followed by a round table discussion led by Mr. Calvert, at which time stream pollution was discussed.

Immediately following the luncheon the party went in cars to inspect the Indianapolis Treatment Works. At the end of the inspection tour, a discussion on sludge disposal was held in the administration building. Mr. Calvert said that at Indianapolis the sludge was pumped to lagoons and was carried away by farmers for fertilizer or for use on golf courses. Mr. Cramer of Milwaukee gave a description of the pressing and drying of activated sludge and of the sale of Milorganite. Mr. Mackin said that they are able to sell their Imhoff sludge at Madison, and that the farmers are very glad to use it for fertilizer.

An evening dinner and smoker was held at the Spink Arms at which time Dr. Thurman D. Rice addressed the group.

The meeting on Friday, June 21, was opened at 9:45 A.M., by Mr. Finch, Vice-President, in the absence of President Cramer.

The first paper was by Mr. E. E. Smith, superintendent of the Elgin, Illinois, Sewage Treatment Plant. He gave an informal description of

the plant, showing slides. A lively discussion followed by Messrs. Hatfield, Finch, Hansen and Downey.

Mr. F. C. Roe of the firm of Shields, Jordan and Roe, consulting engineers in Chicago, presented a paper describing the sewage treatment plant at Princeton, Illinois. This plant uses Simplex aerators for mechanical aeration.

A paper describing the sewage treatment plants at Madison, Wisconsin, was given by Mr. James Mackin, Superintendent. He showed several slides of the plants and, in particular, a slide of a "bug," *achorutes viaticus*, which inhabits the stones of filter beds and destroys the larvae of the psychoda.

In the absence of Mr. Cramer, Mr. Beatty of the Wisconsin State Board of Health, presented an abstract of Mr. Cramer's paper on "Concentrated Sludge in Reducing the Period of Aeration in Connection with the Activated Sludge Process."

A paper presented by Mr. Radebaugh on the "Standardization of Costs in Sewage Treatment Works Operation" was followed by a lively discussion and on the basis of this paper a motion was made by Mr. Hansen as follows:

"I wish to move that the executive committee begin at once to arrange a national committee to follow out the recommendation in Mr. Radebaugh's paper, namely, 'that this organization recommend to the officials of the Federation of Sewage Works Associations that a national committee be developed to standardize a national code of accounting adaptable to sewage treatment works operation, which will make possible standard construction and operation cost for such projects; and that this committee meet with the view of advising on ways and means of obtaining accurate cost data.' "

The motion was seconded by Mr. Finch and unanimously adopted.

Mr. Mackin stated that in his opinion pumping costs should also be standardized. Dr. Hatfield suggested that power costs should be stated separately.

Mr. Hansen recommended that the form of cost accounting should be similar to the form adopted by the American Water Works Association in their standardization committees.

A paper by Messrs. A. H. Goodman and C. E. Wheeler on "Disposal of Sludge at the Calumet Treatment Works" was presented by Mr. Goodman of the Chicago Sanitary District. A discussion followed by Messrs. Radebaugh and Hansen.

Mr. Ferguson then started a discussion on the standardization of the units of measure used in sewage works publications, stating that it would be preferable to keep the metric system throughout rather than having metric for analytical data and English for units of length and work.

Mr. Ferguson moved that the executive committee take the matter up with the National Federation and arrange the appointment of a national

committee with the view of advising on the feasibility of adopting and using the metric system throughout all papers and data obtained on sewage treatment.

Mr. Hansen seconded the motion but asked for an amendment to the motion so that the motion might be put on a broader basis and allow for the adoption of some uniform system rather than restricting it only to the metric system.

The motion as finally adopted was that "the executive committee take up with the Federation the appointment of a national committee to study the advisability of standardizing the units in which to record sewage works data and to adopt a uniform system, either the metric system or a combination of English and metric systems."

Mr. Hansen discussed the "Relation of Consulting Engineers to State Sanitary Engineers in Connection with the Submittal of Plans for Sewerage and Sewage Treatment." A discussion of this followed by Messrs. Finch, Warrick and Mackin.

Before the meeting adjourned, Mr. Finch asked if there were any people who wanted to make any inspection trips in the afternoon and it was arranged to visit the water works. Some of the people also inspected the new Frankfort Sewage Treatment Plant.

It was moved that there be extended to the Indianapolis Section a word of gratitude and thanks for their efficient handling of the Second Annual Meeting and that Drs. King and Rice be thanked for their excellent addresses to the section. It was also moved to thank Messrs. Finch and Calvert for their work in making the meeting a success.

The meeting adjourned at 12:45 for a luncheon and round-table discussion.

The round-table discussion was led by Mr. Lewis Finch who introduced Mr. James Mackin of Madison, Wisconsin, who gave a short talk on "Achorutes Acquatica and Its Relationship to the Psychoda Fly."

Mr. Radebaugh gave a talk on "The Sanitary District Law of 1917, State of Illinois, and Public Relationship with Sewage Treatment Projects."

A business meeting followed and Mr. Hansen, chairman of the nominating committee, reported as follows:

President: Lewis S. Finch, Indianapolis, Ind.
First Vice-President: F. W. Mohlman, Chicago, Ill.
Second Vice-President: L. F. Warrick, Madison, Wis.
Secretary: Gus H. Radebaugh, Urbana, Ill.
Treasurer: C. K. Calvert, Indianapolis, Ind.

Signed by committee,
PAUL HANSEN,
JAMES MACKIN,
CHAS. BROSSMAN.

The above were unanimously elected.

It was decided by motion that the next meeting place would be some place in Illinois. Paul Hansen spoke for the city of Chicago, Harry Ferguson for the City of Springfield, Dr. Hatfield for Decatur and the Secretary for Urbana-Champaign. The selection of the town was left for the Executive Committee.

The Secretary then presented the following proposed by-laws:

1. Classification of membership shall limit Plant Operators to those persons supervising or operating sewage plants in municipalities with a population of ten thousand or less or to employees of plants of larger municipalities, except executives and assistant executives; Corporate Members to any firm engaged in the designing, construction, operation or supervision of sewage works equipment or to any board, commission, department, municipal or private corporation desiring membership as a group; and Active Members to all other persons eligible for membership under Article III of the Constitution.

2. Revised membership list shall be prepared quarterly by the Treasurer based on dues actually received and deposited to the credit of the Association on or before the first day of each quarter beginning July 1, 1929. Copies of this list shall be sent to all officers of the Association and to the Secretary and Business Manager of the Federation of Sewage Works Associations. The Treasurer shall send to the Secretary of the Federation a draft covering annual fees to the Federation of new members and renewals of membership acquired during the quarter. Those members joining the Association after July 1st of any fiscal year shall be entitled to a reduction of dues for the remaining part of the fiscal year, dues to be in accordance with the following schedule: Plant Operators—$1.00, Active Members—$2.00, and Corporate Members—$5.00, with the option of paying full membership dues and receiving back copies of the JOURNAL for the fiscal year.

3. The President of the Association shall appoint State Membership Solicitation Committees composed of two members from each constituent state to coöperate with State Sanitary Engineers, who shall be chairman of these State Committees, in securing new members. The President of the Association shall act as General Chairman of the State Committees.

The above by-laws were adopted by the Convention.

Third Annual Conference of the Pennsylvania Sewage Works Association

Harrisburg, Pa.

July 16–19, 1929

The Third Annual Conference of the Pennsylvania Sewage Works Association was held in the South Office Building, State Capitol, at Harrisburg, Pennsylvania from July 16–19, 1929.

The meetings on July 16th and 17th were devoted to sewage problems. The papers discussed determination of pH in sewage, studies on sludge treatment, gas collection from Imhoff tanks, odor control, studies in sewage and trade waste treatment, and descriptions of some of the Pennsylvania sewage treatment works.

The sessions on July 18th and 19th were devoted to water treatment problems.

On the afternoon of July 17th there was an inspection trip to the Hershey and Lebanon sewage treatment plants.

The complete program and proceedings will be published in the October issue of THIS JOURNAL.

Fifth Oklahoma Water Works Short School

Stillwater, Oklahoma

April 30–May 5, 1929

The Fifth Oklahoma Water Works Short School was held during the week of April 30–May 5, 1929, at Stillwater, Oklahoma, the Oklahoma Water Works Conference, A. & M. College, State Board of Health, and Department of Vocational Education coöperating.

The papers included several on well construction, pumping, operation and maintenance, one on the need of sewage research, and one on algae control.

A two-day inspection tour of nearby sewage and water works was made.

The conference voted to change the name of the Association to that of the Oklahoma Water and Sewage Conference and to affiliate with the National Federation. It was also voted to request the legislature to provide sufficient funds to permit enlargement and furthering of the aims and work of the organization.

The officers include:

President: C. K. Bullen, Stillwater.

Vice-President: Fred Cowell, Lawton.

Secretary: H. J. Darcey, Oklahoma City.

[EDITOR'S NOTE: Word has just been received that the Oklahoma Water and Sewage Conference has been elected to membership in the Federation of Sewage Works Associations by a majority vote of the Board of Control.]

Notice of the First Annual "Inspection" Meeting of the New York State Sewage Works Association

Rochester, N. Y.

July 27, 1929

The First Annual "Inspection" Meeting of the New York State Sewage Works Association is to be held July 27, 1929, at the Hotel Seneca in Rochester.

The morning session will be devoted to business and to papers on sewage problems, which will include "Municipal Wastes," "Simple Laboratory Control for Small Disposal Plants," and "Sludge Digestion."

A description of the Rochester Sewage Treatment Works will be given by John F. Skinner, sanitary engineer, prior to visiting these plants in the afternoon.

The New York State Sewage Works Association has been elected a member of the National Federation by a majority vote of the Board.

Reviews and Abstracts

H. W. STREETER

Recently Constructed Activated Sludge Plants in England

ABSTRACTED BY H. R. CROHURST

Recent tendencies in England in the design of moderate sized activated sludge plants and in methods of aeration are suggested by three English plants placed in operation during the past few months. The processes of treatment and methods of aeration for the installations at Burgh of Airdrie, placed in operation during November, 1928, at Epsom, where a reconstructed plant was started in February, 1929, and a plant at Staveley (Chesterfield Rural District) which started operations in March, 1929, may be briefly summarized as follows.

Burgh of Airdrie. *Surveyor*, **75,** 283 (March 1, 1929).—The plant was designed to treat one million imperial gallons of dry-weather sewage flow but is capable of completely treating storm flows up to three times the dry-weather flow. Flows in excess of three times the dry-weather flow are by-passed after treatment in detritus tanks. The plant consists of two detritus tanks, 10,000 gallons capacity each (30 minutes detention period), screens, two settling tanks, Dortmund type, 42,000 gallons capacity each (2 hours detention period), three groups of aerating channels, total capacity 677,000 gallons, each provided with five aeration pockets fitted with Simplex aeration cones allowing an aerating period of 16 hours, settling tanks in three groups of three each, capacity 360,000 gallons ($8^1/_2$ hours detention period). Power for the aerating cones is furnished by a 30 H.P. motor with a duplicate unit available. Sludge drying beds 5334 square yards in area (equivalent to 1 square yard for about 5 persons) are provided and are constructed of screened clinker and 3 inches of fine ashes. Sludge beds are underdrained and the liquid returned to the aeration tanks.

Epsom. *Surveyor*, **75,** 233 (February 13, 1929).—Previous methods of disposal consisted of broad irrigation to which was added contact bed treatment and later septic tank treatment. In 1925 the adjacent area having been developed close to the disposal site, broad irrigation and septic tank treatment was abandoned and a plant constructed consisting of detritus tanks, screens, sedimentation tanks and surface aeration tanks which were provided with quiescent areas at the corners for secondary sedimentation. This effluent was passed through the old contact beds on the way to

the river. The plant operated satisfactorily and without odor nuisance. It was observed that better results were obtained when the preliminary sedimentation tanks were by-passed. In 1928, when extensions became necessary, the original installation was modified by converting the sedimentation tanks into aerating tanks. The reconstructed and enlarged plant, placed in operation in February, 1929, was designed for a dry-weather flow of 750,000 gallons and consists of detritus tanks, 10,000 gallons capacity (3 hours detention period), twelve aeration tanks, capacity 240,000 gallons ($7^1/_2$ hours detention period), and six sedimentation basins, capacity 240,000 gallons ($7^1/_2$ hours detention period). The effluent from the new plant is being passed through the original contact beds. The aerators are of the Simplex type, driven by a 14 H.P. motor, the power actually consumed being about 11 H.P. Two small sludge pumps of 5 H.P., of which about 1 H.P. is utilized, distribute the sludge for circulation and disposal on land.

Staveley (**Chesterfield Rural District**). *Surveyor*, **75,** 275 (March 1, 1929).—Sewage treatment works of the activated-sludge type were placed in operation during March, 1929. They were designed for a dry-weather flow of 625,000 imperial gallons. Flows in excess of six times this amount are diverted at the head works, and flows of over three times this amount after passing through the preliminary sedimentation basins. The various units of the plant are: detritus tanks (30 minutes detention period), preliminary settling tanks and storm water tanks, Dortmund type (8 hours detention period), circulating and aeration tanks (24 hours detention period) and final settling tanks, Dortmund type (6 hours detention period). The two aeration tanks are each divided into 12 channels with a length of nearly one-half mile and each channel is provided with a paddle wheel of skeleton ironwork 10 feet in diameter to produce surface aeration of the sewage. The power plant consists of two 13 H.P. motors for running the paddles and three 4-inch centrifugal pumps driven by three $7^1/_2$ H.P. motors for circulating the sludge and for its disposal on sludge-drying beds. Sludge beds are of hard burned clinker, 22 inches deep, 6000 square yards in area (equivalent to 1 square yard for each 4 persons).

Disposal and Utilization of Sludge from the Stuttgart Sewage Treatment Works

BY W. SOHLER

Gesundheits-Ingenieur, **52,** 274–76 (April 20, 1929)

ABSTRACTED BY J. K. HOSKINS

The sedimented sludge from the city disposal plant has a water content of 80–85 per cent, which, air dried on sludge beds, is reduced to about

60–70 per cent. The volume of this dried material amounted in 1928, from a population of 355,000, to 54 cubic yards per day. Machine removal from the drying beds is effected at one-third of the previous cost of hand labor.

A comparison of fertilizer value of this sludge with other forms of manure is afforded in the following tabulation:

	Sewage Sludge	Privy Soil		Dung from	
		Pit	Vault	Cattle	Horses
Weight per m^3 in kilograms	850	960	960	980	980
Water content, %	60	92.3	96.3	75.7	71.0
Total nitrogen, %	0.7	0.36	0.75	0.42	0.58
Available nitrogen, %	...	0.1	0.42	0.15	0.20
Total phosphoric acid, %	0.6	0.16	0.27	0.25	0.28
Available phosphoric acid, %	...	0.06	0.12	...	...
Potassium, %	0.2	0.15	0.29	0.50	0.53

Continued experiments by the agricultural college having demonstrated the practical value of the sludge for increasing the yield of certain crops, an active demand was created for it following the war. In 1924 this wet sludge was sold at 50 Pfennigs per cubic meter but in the following years it was given away. However, because of transportation costs, a limited market only is available for disposal of this kind of material. Attention was therefore devoted to the production of a dry sludge fertilizer. A mixture consisting of 1 to 2 parts of sludge and 1 part peat with wet night soil was prepared. Later the sludge was first dried with waste heat from the electric plant, mixed with the peat and night soil, pulverized and sacked in 50 Kg. (110-lb.) bags. This fertilizer contained 1.1% N, 1.2% phosphoric acid, 0.2% K, 32 per cent organic material, 45% ash and 22% water. The cost of preparation was 1.10 M per 100 Kg. and it found a ready market at 1.50 M per 100 Kg. The commercial feasibility of such disposal was therefore demonstrated by the city.

However, soon afterward, waste heat from the electric plant was no longer available for sludge drying, and other sources of heat being too expensive to install, it seemed best to interest private capital.

Such an opportunity was afforded by a private firm who had previously been producing a very satisfactory fertilizer consisting of a mixture of sewage solids and peat. It was determined that the precipitated sludge could be readily substituted for the fresh solids and they therefore installed the necessary mixing plant near the sewage works. The air-dried sludge is sold to this firm at 20 Pf. per cubic meter. An increasing demand for this mixed fertilizer is indicated, the present sale price at the works being 12 M per cubic meter.

[EDITOR'S NOTE. Sohler's estimates of the cost of operation by hand and by machine may be of interest. The machine has a capacity of 44 cu. meters (57 cu. yd.) per hour and requires 15 H. P. for operation. A

photograph of the machine was shown in the article by S. A. Greeley on "Sewage Treatment in Europe," THIS JOURNAL, Vol. 1, p. 229, Jan., 1929.]

By Hand:	6 men remove 50 cu. meters per day	
	Labor at 10 M. ($2.40) per day	
	Cost per cu. meter—1.20 *M.*	
By Machine:	Cost of machine	19,000 M.
	Int. and depreciation at 10%	1900 M.
	Service, one man, 10,000 cu. m. per year, 100 cu. m. per day, 100 days at 10 M. per day	1000 M.
	Power, 65 K. W. hr. per day, 10 pf. (2.4 cts.) per K. W. hr., 100 days	650 M.
	Oil, grease and supplies	200 M.
	At 10,000 cu. meters per yr.	3750 M.
	Cost per cu. meter—0.375 *M.*	

The Depth of Sewage Filters and the Degree of Purification

BY A. M. BUSWELL, S. S. STRICKHOUSER AND OTHERS

Illinois State Water Survey, *Bulletin* **26** (August 7, 1928)

ABSTRACTED BY C. T. CARNAHAN

Previous Work.—A survey of the previous work on the question of the progress of purification at different levels in a trickling filter shows that when filters of different depths are dosed with sewage at the same rate per unit of surface area, and the same volume of sewage flows through the different filters, the rate of purification is greatest where the sewage concentration is greatest, that is in the upper part of the filter. Experiments conducted on the basis of equal dosage per unit of volume do not give such results. Consider, for example, two filters of 4′ and 8′ depth and with equal surface areas. If both filters are treated with equal amounts of sewage per unit of volume, the deep filter will handle twice as much sewage as will the shallow filter. Hence, twice the amount of sewage will trickle over any given depth of the deep filter as will trickle over the same depth of the shallow filter and the deep filter will not purify the sewage so well as the less heavily dosed shallow filter for the same depth, and the value of the upper portion of the filter is obscured. Conclusions based on this method of dosing led the Royal Commission on Sewage Disposal to conclude, in 1903, that the same results could be obtained from a given volume of filter material regardless of its arrangement, within certain wide limits. This erroneous conclusion has controlled the design of sprinkling filters for years. The conclusions were erroneous, for although the dosage

per cubic yard remained constant, and the filter area was constant, the volume of sewage treated increased in proportion to the depth of the filter and the results of the different filters were not comparable due to the unequal loading.

Experimental Procedure and Results.—The experimental work was carried out at the Urbana-Champaign Sanitary District treatment plant. The filter plant consisted of two 10-foot filters, each having an area of 0.8 acre. The stones were laid with a 6-in. layer of $2^1/_2$-in. to $4^3/_4$-in. stones on the bottom and a 9-ft. 6-in. layer of stones not less than 1 in. nor greater than 2 in. in size. Sprinkling nozzles of the Taylor type were used, with specially designed half nozzles at the sides of the bed. Two 30,000 gallon dosing tanks provided for alternate dosing of the beds.

Normal domestic sewage, with practically no trade wastes, was used. The sewage was settled in 4 Imhoff tanks after screening.

Sample collection pipes were installed at the 2-, 4-, 6- and 8-ft. levels of the east filter during construction.

Samples collected were "catch" samples and represented the flow of one complete spray.

Samples were analyzed at once. All analyses were made according to the Standard Methods of the A. P. H. A.

The samples were grouped into the following series:

Series A. 24-hr. composite samples collected every sixth day, from the raw sewage, the Imhoff tank effluent and the filter plant effluent.

Series B. "Catch" samples from influent, 2-, 4-, 6-, 8-ft. and effluent pipes of filter each Tuesday at 10 a.m., with weak sewage.

Series C. "Catch" samples from same sources as B each Tuesday at 4 p.m., with strong sewage.

Series D. "Catch" samples from same source as B every sixth day at 2 p.m., with fairly strong sewage for each day of the week.

Series E. Samples collected from east filter running under heavy load due to closing down of west filter, with high filtration rates.

Series G. Samples collected after west filter was again put into operation and load on east filter reduced.

The data gathered from the above samples show the following results:

1. The quality of the effluent obtained from the 10-ft. level of the filters is no better than that from the 6-ft. level.

2. The additional depth beyond 6 ft. does not cause a more satisfactory effluent at higher rates of filtration. Moreover, ponding and clogging become the limiting factors in the use of high rates of filtration.

3. The results show that there is an optimum depth of filter beyond which it is not necessary or advisable to go. In this case the depth was found to be 6 ft., but with some other sewage and different conditions, the optimum depth may be different.

4. Shallow filters at lower rates of filtration probably are better than deep filters at higher rates because: (a) the cost of pumping the sewage a greater height than necessary is eliminated, (b) the lower reaches of the deep filter are not very effective and are therefore wasted, (c) if the rates are the same for both deep and shallow filters, the advantage of the deep filter disappears, as all of the depth below the optimum is wasted.

5. Because of the lessened surface area of the large stones placed in the bottom of filters to prevent clogging, there is a loss in the efficiency of the lower reaches of the filter. The weak concentration of sewage near the bottom needs a large contact area in order to remove more of the residual material in the partially purified sewage and increase the efficiency of the lower parts of the bed. It appears that a better arrangement would be filtration of the sewage, first through a bed of coarse material to remove much of the colloidal material and, finally, through a bed of fine material to remove the residue. The filters could be operated at higher rates, but the cost of the double pumping probably would be excessive.

Bio-precipitation Studies, 1921-1927

BY A. M. BUSWELL, R. A. SHIVE AND S. L. NEAVE

Illinois State Water Survey, *Bulletin* **25** (June, 1928)

ABSTRACTED BY EMERY J. THERIAULT

In a previous publication (Illinois State Water Survey, Bulletin 18) the conclusion was reached that the flocculated material either on the rocks of trickling filters or in an activated sludge tank is composed principally of microbial growths. In extension of these studies, the first part of the present Bulletin deals largely with problems of aeration in the activated sludge process while the second and third parts are devoted to a consideration of the "nidus" tank.

Ingenious experiments are presented tending to show that an air bubble in its ascent through water carries with it "a nearly intact shell of water which prevents any change of the air-water interface ...." A marked increase in the rate of absorption is noted when baffles are interposed in the path of the bubbles, "the aim being to scrape off the shells" before the bubbles reach the surface.

In other experiments oxygen-free water was trickled in a thin sheet over a spherical bulb, the thickness of the film being varied by altering the rate of flow. The reaerated water was collected by displacement in a sample bottle for the determination of dissolved oxygen. The rate of reaeration is shown to vary uniformly, although not directly, with film thickness. By extrapolation, it appears that "for saturation to occur in 0.2 second, the film thickness must be less than 0.01 millimeter."

Experiments were also made to determine the relative efficiencies of various mechanical aeration devices. "An endless canvas belt operating half-submerged in a vertical position around two rollers, one in the tank bottom and the other above the water level" gave good results. Better results were obtained with "a rack composed of 80 vertical strings supported by two perforated end-plates .... This rack was lifted out of the liquid at regular intervals by a suspension wire connected over a pulley to a motor-driven crank."

On the basis of these aeration experiments it is concluded that sewage can be clarified by simple mechanical mixing, without the use of compressed air. "If mixing and sludge suspensions are not dependent upon the air introduced, clarification by the activated sludge process requires less than 0.01 cubic feet of air per hour per gallon of sewage."

Passing to the second part of the Bulletin ("The Rôle of Bio-precipitation in Sewage Treatment" by R. A. Shive and A. M. Buswell) it will first be necessary to consider the meaning attached to "bio-precipitation." Essentially, it is defined as the process, in virtue of which sewage colloids are taken up "by micro-organisms of such growth habits that they form large compact flocs which will settle out." "Bio-precipitation," therefore, is closely related to the adsorption or assimilation of food materials by living organisms. The further stipulation that the organisms themselves should constitute the floc appears warranted in certain cases. Thus "The young vegetative filaments of B. subtilis formed compact rapidly settling flocs." In this connection the interesting observation was made that "as the cultures grew older and the food supply less abundant, spore-formation set in; the filaments were thereby weakened at various points and began to break up. The result was feathery non-settling flocs, a typical 'bulked' sludge. In this case over-ripeness was undoubtedly the cause of bulking."

The balance of the Bulletin is devoted to a study of the "nidus" tank method of sewage treatment. A nidus tank is a tank in which a series of mats are suspended from racks. The mats are woven from strips of veneer or basket-wood. A large surface is thereby provided for biological growths. In a sense the "nidus" tank is an improved form of trans-colloider or brush-wood filter. For highest efficiency it is necessary to shake the growths from the racks at suitable intervals. The growth of the activated-sludge organisms is accelerated when compressed air is supplied to the sewage at the rate of 0.0015 cubic feet of oxygen per gallon of sewage. The "nidus" tank is said to be intermediate between ordinary tank treatment and trickling filters. "The estimated cost, $3000 per million gallons, or even twice that figure, would seem a reasonable amount to pay for the increased efficiency obtained by nidus racks."

[EDITOR'S NOTE: Dr. Buswell described the construction and operation of the nidus rack in a paper in THIS JOURNAL, **1**, 187–195 (Jan., 1929).]

Pollution of Streams and Rivers[1]

ABSTRACTED BY C. T. WRIGHT

Amendment of the Rivers Pollution Prevention Act, 1876. By JOHN D. WATSON. *Surveyor*, **75,** 509–11 (May 17, 1929).—Under the Rivers Pollution Prevention Act of 1876, the administration of the law was entrusted to the various sanitary authorities then existing.

The Act seeks to give manufacturers the right to connect drains to public sewers, but that right is so hedged in with qualifications that it is practically useless, unless the local authority is sympathetic and removes disturbing elements.

To remedy the evils existing under the present Act, the Royal Commission on Sewage Disposal made workable recommendations to set up a central authority, capable of giving final decisions without reference to the courts. Whether the power of the central authority should be vested in the Ministry of Health or in a committee of specially qualified men is still a question.

Local authorities and manufacturers look for a definite and responsible authority, which would direct as well as guide, thereby saving money in useless litigation, and making available sound advice on treatment.

Formation of Rivers Boards for the Whole Watershed Area of a River. By H. F. ATTER. *Surveyor*, **75,** 553–4 (May 31, 1929).—The formation of river boards under the control of one central authority has been urged to secure the proper administration of the laws restraining the pollution of the whole area drained by a river and its tributaries.

The Rivers Pollution Prevention Act of 1876 was modified by the Local Government Act of 1888 which gave the Local Government Board power to constitute a Joint Committee representing all the administrative counties through or by which a river might pass and to confer on such a body all the powers of a sanitary authority under the Rivers Pollution Prevention Act.

In 1891, Joint Committees were formed for the control of the rivers Mersey, Irwell and Ribble. The same procedure was followed in 1893 covering the whole of the West Riding of Yorkshire. These precedents established the fact, without new legislation, that joint committees or river boards covering any area could be formed.

The West Riding of Yorkshire Rivers Board has jurisdiction over a total length of 2000 miles of river and stream. There are in its area more than 2000 mills and factories producing trade effluent and 432 sewage-disposal works. The area is divided into 10 districts, each under the charge of a district inspector, whose work is controlled and directed by the chief

[1] *Papers presented at the Conference of the Royal Sanitary Institute, London, May, 1929.*

inspector. The Board have their own laboratory, and a legal and administrative staff.

[EDITOR'S NOTE. A communication from Reg. C. Shaw, Esq., clerk to Mr. J. H. Garner, F.I.C., states that the latter has been appointed Chief Inspector by the West Riding of Yorkshire Rivers Board, vice Dr. H. Maclean Wilson, who has retired after 32 years of service. Dr. Wilson and Mr. Garner are well known for their outstanding work in this important manufacturing district, and their reports are of great value both in England and America. On Dr. Wilson's retirement he was presented with a gift of bank notes, subscribed by present and former members of the Board, also an engrossed vellum copy of their resolution of thanks and esteem. Mr. Garner's address is Wakefield, Yorkshire, England.]

Prevention of Pollution by Domestic Sewage and Industrial Wastes: Technical Aspects. By ARTHUR J. MARTIN. *Surveyor*, **75,** 510–12 (May 17, 1929).—The Royal Commission on Sewage Disposal devoted much attention to the standards for effluents, but did not recommend a standard bacteriological test. An effluent would, they considered, be generally satisfactory if it did not contain more than 3 parts per 100,000 of suspended matter, or, with its suspended matter included, take up in 5 days at a temperature of 65° F. more than 2 parts per 100,000 of dissolved oxygen. This standard has not yet received statutory recognition, and most of the river boards have adopted provisional standards of their own.

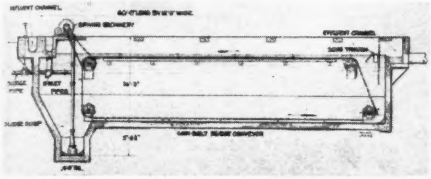
The methods of treating domestic sewage in England are fairly well established, but there is still much to be learned as to the best methods of treating trade wastes.

The chief hindrance encountered to place the purification of sewage on a firmer scientific basis and to restore the rivers and streams to something like purity are not technical but financial, legislative and administrative. In many cases badly-needed schemes of sewage disposal have been held up by lack of funds or were delayed by old restrictions limiting the borrowing powers of municipalities.

* * * * * * * * * * * *

In the discussion of the papers covering rivers pollution, differences of opinion were expressed as to whether it would be advisable to form rivers boards clothed with central authority or to continue under the present laws and endeavor to exercise the existing powers to the fullest possible extent.

A Page of Ideas for Economical Disposal of Sewage



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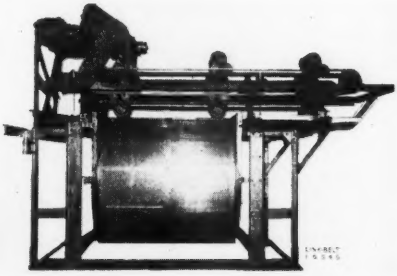

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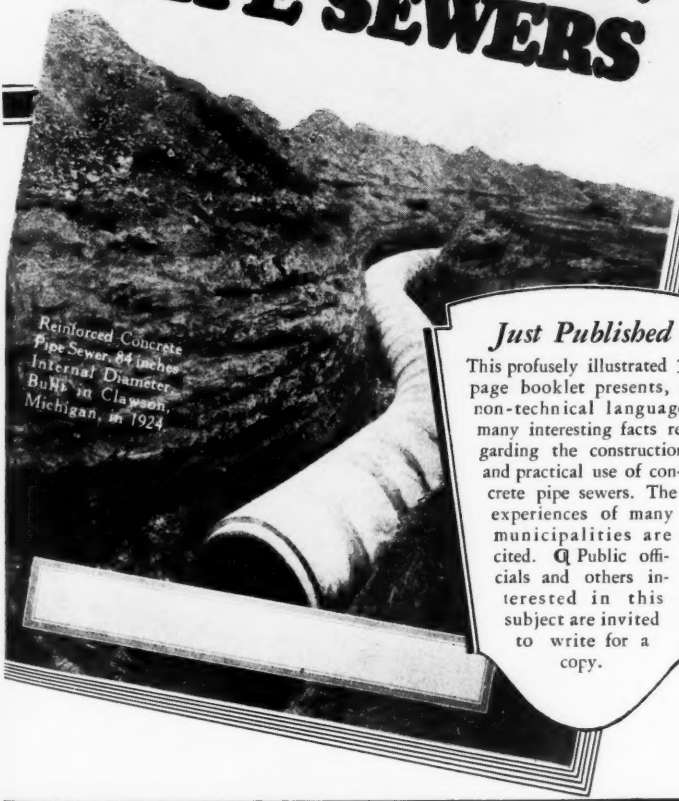

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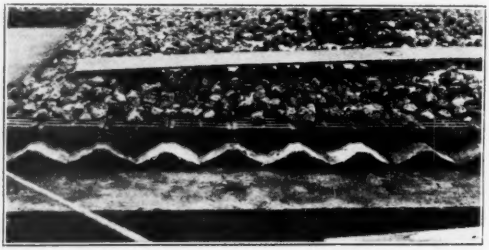

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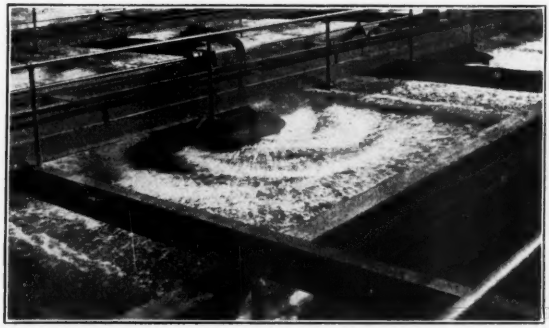

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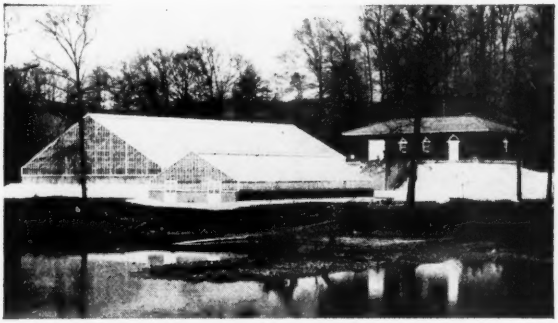

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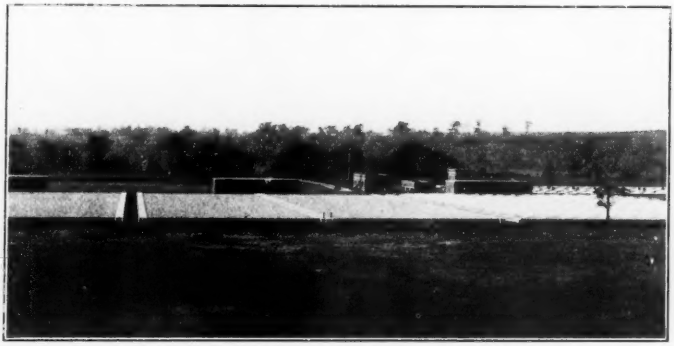

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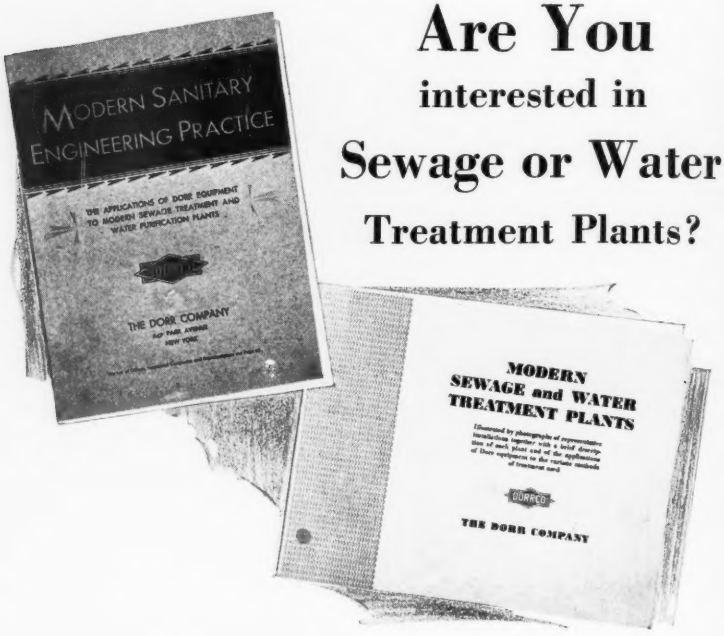
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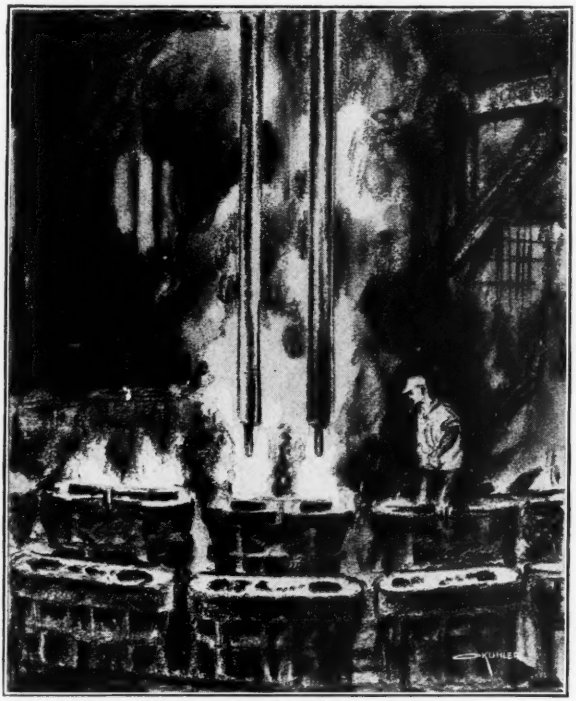

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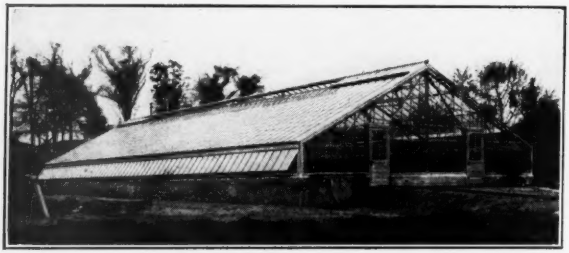

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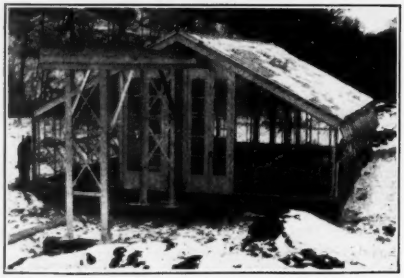

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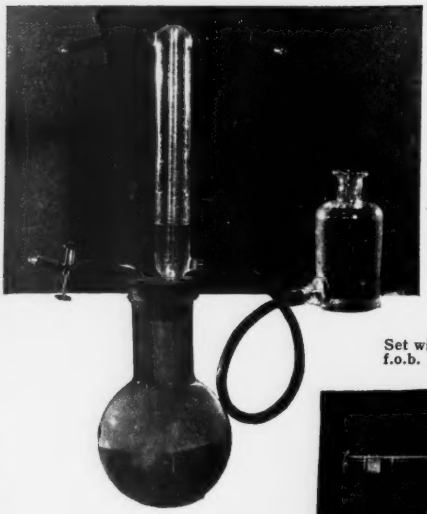

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